Final Technical Report

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Investigation of Forestry Resources and Other Remote Sensing Data

February 1, 1980 - Oct. 31, 1983

I. Landsat

II. Remote Sensing of Volcanic Emissions

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This represents the Final Technical Report for NASA Cooperative Agreement NCC 5-22. This cooperative agreement represents a continuation of NASA Grant NSG 5014 which ran between July 1, 1974 and March 31, 1980. Some of the projects undertaken in NCC 5-22 are carry-over projects from NSG 5014.

The details of the work done under NCC 5-22 have been covered in the Semi-Annual Reports, but an overview of the major aspects of the work effort is given below.

I. Landsat

The major effort of the Cooperative Agreement has been the work of Emily Bryant and the forestry group who have used computer classification of Landsat data for forest type mapping in New England. Appendix A represents a major summary of the forestry work at Dartmouth and Appendix B is a summary of the work accomplished by Gibb Dodge and his colleagues at the University of New Hampshire Cooperative Extension Service in Cooperation with Dartmouth College.

II. Remote Sensing of Volcanic Emissions

The principal activities of the group concerned with remote sensing of volcanic emissions centered around the development of remote sensors for SO_2 and HCl gas,and their use at appropriate volcanic sites. We were involved in two major areas, Masaya, Nicaragua, and St. Helens, Washington and several minor ones. Travel funds were supplied by others to allow deployment of our instruments. Such funds also allowed attendance at meetings at which our volcanic gas work was reported.

The correlation spectrometer was used successfully at many volcanoes to measure SO_2 flux. A chapter was contributed to the book "Volcano Forecasting" in which we discussed the use of the correlation spectrometer as a tool for remote sensing (Stoiber et al., 1983, See Appendix E). We developed a simple real time computer link for the Cospec. A small version of the Cospec was field tested with promising results. The HCl remote sensor, Gaspec, was modified extensively,but field tests were inconclusive. The limit of sensitivity of HCl may not have been sufficiently improved to allow successful use of the instrument in the field.

St Helens. Our part in the scientific observations and study of the products of Mt. St. Helens encompassed four periods which were both before and after the major eruption of May 18, 1980. We determined that gases before the eruption contained a small magmatic component as compared with those during and after the eruption. Our method of measuring the SO_2 flux was adopted by the U. S. Geological Survey Observatory staff who monitor the volcano. The Rave mission of September, 1980 in which our group participated was an effective collaboration of several scientists in joint studies of the gases. Reprints enclosed in Appendix F. (Stoiber et al., 1980; Stoiber et al., 1981; and Casadevall et al., 1981) report the results of our St. Helens work. Our effective and extensive cooperation within the media (press, radio and television) during the period of major eruption served to help inform the public accurately about what was going on.

Masaya, Nicaragua. The volcano is giving off unusually large quantities of SO_2. We have studied the SO_2 flux and the associated gases with a group of scientists brought together from several disciplines the group studied the nature of the gases, the effect on rain, on soils, and on plants. Some observations relative to the effect on health were made (Stoiber and Williams, 1982 in Appendix F.). SO_2 flux was large but showed major variations from day to day. We attempted unsuccessfully to correlate major fluctuations with earth tides although some minor changes may be related. Several variations in flux remained unexplained. The final report on this project is in preparation although there have been interim publications (listed in Appendix E.).

Other efforts during the program included the pioneering of Cospec use in a plane flying through and beneath volcanic plumes during the NCAR mission to study volcanoes in Guatemala, Feb. 1980, of which we were a part (see Appendix E.). Our study of gases at Fuego volcano integrates much of our data (Rose et al., 1982 in Appendix F.). We have also contributed to keeping abreast of volcanic eruptions in the standard reporting system of the Smithsonian, the SEAN reports, (Appendix E). We have been joint authors on a general paper on the volcanism of Central America (Carr et al., 1982 in Appendix F.).

Much of the gas measurements are now being brought together in a paper being prepared for publication this year in which the annual flux from volcanoes of SO_2, HCl, HF and HBr is estimated. This is a result of our volcanic studies of the past years in which NASA support has played an important role.

III. Status of Remote Sensing at Dartmouth

During the course of this grant the data link between Dartmouth and the Goddard Institute for Space Studies was discontinued. This link had served the research effort since 1974 including NASA Grants NSG 5014, NCC 5-22, and NAG 5-159. In addition, the link was used extensively in educating Dartmouth students to the use of digital processed Landsat Data. Numerous graduate and undergraduate students ran projects and theses on the system, and many more students took a formal Dartmouth course, Earth Science 32 "Applications of Remote Sensing to the Earth Sciences" which made extensive use of the system.

However, remote sensing will not end at Dartmouth now. Two systems useful for instruction of students have been developed for the Dartmouth System as a part of this project. These are the GIGI SHOW Package developed by Emily Bryant (Appendix C) and the DRESS Package (Dartmouth Remote Sensing System) developed by Paul Fisher as a part of the undergraduate course, Earth Science 32 (Appendix D). We anticipate using both of these systems in future student instruction.

In addition to the above two systems developed for use on the Dartmouth mainframe computer, the Earth Science Department has purchased the APPLEPIPS Image Processing System to run on our Apple IIe computer. This will also be used for in house work.

The research efforts will be continued by Birnie who has proposed to NASA through J.P.L. a remote sensing study using Landsat 4 data.

IV. Bibliography and Reprints

A bibliography of papers published under the auspices of this grant, including some carried over from NSF 5014 is given in Appendix E. Some of the work initiated during the earlier grant had not been published by the time of its final report. They are, therefore, included herein. A collection of some of the most significant reprints are also provided in Appendix F.

APPENDIX A

Forestry Report

by

Emily Bryant

Table of Contents

0. Introduction and Summary

The NASA grant to Dartmouth for investigation of earth resources via remote sensing was established in 1974 and will end in mid - 1983. In the interrim, many people have been exposed to Landsat and its capabilities, and many have learned how to extract information from digital data. The goal of the forestry group has been to use computer classification of Landsat data to make useful forest type maps for the field forester. Techniques for classification of forests in New England have been developed, and they have been tested on application areas. We have found that Landsat can be used to map New England forests, and recommend that we move on to operational systems. Details follow.

I. Major Projects

A. Coos County In this first major project, Landsat data of Coos County, NH was classified using a simple set of five forest, one open, and one water signature. Using a sample area, the five Landsat forest categories were calibrated to match the two categories (softwood and hardwood) used by the US Forest Service in their inventory of New Hampshire forests. Using this calibration, Landsat acreages of softwood and hardwood for the whole county turned out to be within 10% of Forest Service acreages. Cheshire County was also classified, with similar results.

Although the techniques used here were somewhat primitive (no boundary program available, and geometrically uncorrected data), the project demonstrated that Landsat data could have useful forest information in it, particularly in inventorying softwood and hardwood types. This project was presented as a short paper at the LARS symposium, and was published in the Journal of Forestry and the Mount Washington Observatory Bulletin.

B. Seven Islands. The Seven Islands Land Company manages about 2 million acres of forest land in northern Maine and New Hampshire. The project we did in cooperation with them was in a way a refinement of the Coos County project. Landsat data was geocorrected, a boundary program was available, and the ground truth available to us was more detailed and thorough than the Forest Service figures. Landsat categories were again calibrated to "ground truth" categories using a sample area. Acreage tallies of hardwood, mixed wood, and softwood were made for each of the 29 townships comprising the Ashland District. For the area as a whole (1/2 million acreas), the Landsat classification acreages came out to within 5% of the Seven Islands inventory information. Cost estimate: 2.6 cents per acre. This was a good project ! Landsat measured up quite well to hard ground truth data. It was presented at the National Workshop on Integrated Inventories of Renewable Natural Resources, published in the proceedings of this, and published in a slightly different form in Photogrammetric Engineering and Remote Sensing magazine.

C. Clearcuts. This project was not as well defined as the previous two, perhaps because ground truth is harder to come by for clearcuts. Numerous clearcut areas in northern New Hampshire were classified in various years. We learned two basic things from this effort: First, clearcuts of about 10 acres or larger can be detected using Landsat, but they confuse with other open areas. Second, change in clearcuts due to rapid regrowth can also be detected. Although we tried to quantify these results, they are really more qualitative than quantitive. This did, however, add a new dimension (forest vs. open) to the Landsat forest classification repertoire, which previously concentrated just on the softwood vs. hardwood distinction within the forest category. This was presented as a poster paper at the 13th ERIM symposium, and was published in the proceedings thereof.

D. Gypsy Moth. The area corresponding to the Keene, NH USGS 15 minute quadrangle was classified using 1973, 1980, and 1981 Landsat data, to see how useful Landsat might be in monitoring the gypsy moth defoliation which occurred in 1980 and 1981. Heavy defoliation could be detected in the classification, but medium and light could not. Although we tried to develop distinct categories for defoliation, it, like the clearcuts, seemed to confuse with the other open categories. One can use a time sequence to separate defoliation, which is a dynamic feature, from open areas, which are relatively static. This opens a whole can of temporal signature extension worms, which are addressed in E. below.

The gypsy moth classification maps were not timely enough to be useful to people in NH who were concerned about where and whether to spray for 1982. This was due to several things, including new format "square pixel" tapes and Emily's working 1/2 instead of full time. The lesson to be learned here is not so much that defoliation can be detected, but that the process of making maps needs to be streamlined. This project was written up but not published or presented.

E. Fudge Factor. (The Infamous). The "fudge factor" technique is a method of temporal signature extension which developed during several projects over the course of the grant. It was particularly relevant in mapping clearcuts and gypsy moth defoliation because they change over time. The approach taken was to determine a linear correction transformation for each spectral band in a new Landsat pass to compensate for atmospheric and other differences between it and a base pass. The new data would then be transformed so that the signatures from the base pass could be used directly on the transformed data. This technique was tested most thoroughly as part of the gypsy moth project, where five passes, all in July, were classified with the same signatures, but with data corrected by fudge factors.

The fudge factor technique seems to work well qualitatively -- it puts land features in the right category and in the right place -- but not quantitively -- acreages of unchanged features between passes are too variable to be useful. I still think the area is worth working on because:

1) Sometimes the FF technique does work well, even quantitatively, and I have not yet figured out whether we could conquer the variability or what causes it.

and 2) If people are going to monitor changes in the landscape using Landsat, it is really important to have some way of making categories that are consistent over time.

This technique is partially discussed in the ERIM clearcut paper, and I hope to write it up more thoroughly soon.

F. Fanning. The Ashland District (same data as in the Seven Islands project) was classified using the fanning algorithm. The fanning algorithm is useful in a landscape consisting of two pure types (in this case softwood and hardwood) and continuously varying mixtures of the pure types. In theory it quantifies the proportion of pure types in the mixture pixels. In this application, the fan had to be partitioned differently than expected to match the four ground truth categories (softwood, SH, HS and Hardwood). Once partitioned using a sample area, however, it was consistent over the whole district. In this project, then, as in others, we found that if you want to match Landsat categories to users' categories, you really need a sample of the users' categories -- a mere description, such as "25% hardwood" is not enough. This project was presented as a poster paper at the 15th ERIM symposium, and was published in the proceedings.

G. MAPPIX. As a summer internship for the Computer and Information Science Program, Emily attempted to design a user-oriented Landsat / Geobased information system. Design was done, but a prototype was never completed. If a geobased information system ever gets started at Dartmouth, this could perhaps serve as a starting point. The system is not oriented toward graphic devices, which could be a mistake, but on the other hand, it is theoretically independent of any device, which is a bonus.

The internship is described further in a report, and there is a notebook of information on the project.

II. Applications.

A significant part of the accomplishment of the forestry section was in establishing contacts with practicing foresters and in application of techniques developed in projects to their areas of concern. Some of the more important applications are described below.

A. Forest Fire. Softwood, hardwood, and clearcut signatures were used in a Landsat classification of the Plymouth and Rumney 15 minute quadrangles for John Ricard, the local Forest Fire District Chief. Softwood and clearcuts, areas of higher fire hazard, were his areas of interest. The Landsat categories were accurate enough to be of some use, but before the maps could be practical, some improvements would have to be made: the maps would have to be in their standard format (1:62,500 scale), be combined with topographic information, and be cheaper.

B. Deer Yard. Deer yards are associated with dense softwood areas. Howie Nowell of the New Hampshire Fish and Game Department found Landsat printouts of several towns in southwestern New Hampshire useful in locating potential deer yards, especially since his funding for field personnel had been cut back. He is in fact arranging to get more Landsat maps through Gary Smith at the University of Vermont (since Dartmouth can no longer provide them). He is perhaps the sole example of a person who has seen our Landsat work and pursued it on his own because it seemed like the most practical way of doing his job. This was presented at the 1981 LARS symposium by Kevin Doran.

C. Belknap County. Belknap County, unlike the other three counties in the NH North Country R C and D area, did not have a forest type map. Through cooperation with the Belknap County Extension Service and the North Country R C and D, Landsat signatures from previous work were field checked, modified to suit the needs of the local foresters, and a Landsat classification map of the county was made. The output was in two forms: a 1:62,500 scale reduction of the lineprinter output, and a photographic product made courtesy of NASA's ERRSAC program. This made from a tape of the classification using their film recorder. This was significant, not only because the county was classified, but also because it meant that something produced here could in fact be exported and successfully put on another system (admittedly with quite a few false starts).

D. White Mountain National Forest. Signatures developed to classify clearcuts were used to classify the entire White Mountain National Forest (about 800,000 acres). Reaction from the foresters was that the map was better for high level foresters than for field foreaters. I think it would have been different if the output had been a color picture instead of yards and yards of paper printout, which is hard to take in.

III. Concepts, Techniques, and Programs.

As particular projects and applications progressed, certain classification techniques, computer programs, and ways of looking at things developed.

A. Signature Package Concept. At first we treated spectral signatures as stand-alone items: once developed, we felt they could be catalogued and stored and subsequently pulled out in a mix and match fashion according to the application at hand. As it turns out, however, the performance or accuracy of one signature is dependent upon the other signatures being used with it in a classification. For example, order of signatures and amount of overlap between one signature and another affect a classification, but cannot be determined from individual signatures. All in all, one must evaluate a classification or package of signatures as a whole.

B. Rational Signatures. Given signatures for two or more pure types, one can create signatures for mixtures of the two types without having any training site for them. This is done by interpolating between the signatures of the two pure types (similar to the fanning algorithm). Sometimes this is convenient when mixture areas are small or ground truth for them is less reliable than for the pure type areas. This points out an advantage of a classification system such as ours which does not make signatures directly from training sites (Usually this seems like a disadvantage.) Exactly what the proportions are of the pure types in the mixture pixels is not known.

C. DELTAS and OPTIMIZE Programs DELTAS was written by Emily and OPTIMIZE was written by Michael Bruzga as a project for ES 32 (Remote Sensing). These are programs which give graphic (DELTAS) and quantitative (OPTIMIZE) predictions of the performance of a set of signatures on a specified range of classification parameters. They are based on reflected radiance values from training sites These programs can be used as a preliminary tool in developing a signature package. The idea is to avoid the effort and confusion involved in the trial and error approach. The bottleneck in these procedures is the manual connection between the GISS computer (where the data are) and the Dartmouth computer (where the DELTAS and OPTIMIZE programs are).

D. TWIST Program. This program was written by Dan Goodwin and is on the GISS computer. It takes a classified map as input and can rotate, change scale, and change symbols, to create Landsat printouts to match maps or photos which are at a scale or orientation different from the standard lineprinter output. It can adjust scale independently for the X and Y directions, and can thus compensate for the new square-pixel format tapes. The source code is in file EFESB.TWIST5 and is well documented in the code as well as in a writeup which Emily has.

E. REGISTER Program. This program is on the Dartmouth computer. It creates a linear transformation between the pixel coordinates of two Landsat passes given the coordinates of three ground control points. It works very well on areas of about 400 by 400 pixels and is very useful when trying to locate corresponding features on two Landsat passes. It suffers from the same problem as DELTAS and OPTIMIZE -- manual transfer of coordinates between GISS and Dartmouth. In my opinion, a program such as this (perhaps more sophisticated) should be an integral part of any geographic information system which aims to be practical.

F. CLASSIFY Program. This is also on the Dartmouth computer. It is a primitive classification program which has the GISS algorithm, Box algorithm (rectangular parallelepiped), Euclidean distance algorithm, and a simple unsupervised classification. It is quite inefficient and un-robust, and is limited to classification of Landsat data which are in terminal format files on the Dartmouth computer, but it has served as a demonstration piece in classes.

G. DRESS. Paul Fisher wrote this as a term project for ES 32 (remote sensing.) From Landsat data, it can make gray scales, print out counts and energies, and select windows of data. The data is in random access files, which makes it faster. It is more user-friendly, robust and efficient than CLASSIFY.

H. SIGPACK. The file EFESB.SIGPACK is on the GISS computer and consists of descriptions and listings of signature packages developed and used in the forestry group over the past eight years. The signatures and parameters are in such a format that they can be "COPY"ed directly to a classification program using Wylbur. It seems as if this could be one of the more useful legacies of the forestry group. See Appendix A1 for a listing of EFESB.SIGPACK.

I. Color Printouts. Following the example of people at Colorado State, we ordered several colors of ribbons for the lineprinter and found that, with some effort, color printouts could be made. One printout is run through the printer several times, with different symbols and different color ribbon each time. Better than black and white, but certainly not a production procedure !

IV. Things That Never Worked. (Perhaps this should be left out !)

There are always some things that work better than others. Here are some that did not work out well, together with some speculations on why they did not. Perhaps someone can learn from our experience.

A. Poplar. Poplar stays green longer than other hardwoods in the fall, so one would expect that distinct signatures could be developed for these types. We found, however, that

1) Things other than poplars (e.g. alders) also stay green, and 2) Both latitude and altitude affect the phenological stage of the tree so much in the fall that spatial signature extension is very limited.

B. Pine-hemlock vs. Spruce-fir. We never licked the problem of separating these softwood types in classification of Landsat data. The pine-hemlock signature seems to fall directly on the continuum between the pure spruce-fir and pure hardwood signatures and thus confuses with a mixture of these two types.

C. Tree Density and Size. Some indication of density of trees (e.g. almost clearcut vs. full canopy) and size (e.g. sapling vs. mature) can be found in Landsat data, but we have not been able to get a detailed enough distinction to help significantly in estimation of timber volume. Perhaps the better resolution of Landsat 4 will help here.

D. Spruce Budworm. We tried to classify areas defoliated by spruce budworm, but were not successful. Gibb thinks it is because the areas of defoliation are too small and scattered. I think that it is also made difficult because there is no ground truth detailed enough to use in developing signatures.

E. Groveton Papers Company. A map was made of one of the compartments of Groveton Papers Company land in northern New Hampshire. Unit boundaries and roads were superimposed using the line program. Although the folks at Groveton have been helpful over a long period of time, this map did not seem to go any place. Some possible explanations are:

- They were too busy at the time to embark on something new.
- Our turnaround time in making the maps was too slow, perhaps due to among other things, the awkwardness of using some of the GISS system.
- The output is cumbersome.

F. Time History and Multitemporal Classifications. Little was done in this area, largely because there was no registered data available. This meant that changes in the landscape over time had to be monitored by visual rather than automatic comparison of classifications at two points in time.

G. Ramtek. The Ramtek color CRT display at Dartmouth worked for a while in about 1976,1978, and then in 1982 at CRREL. The rest of the time it did not function due to both hardware and software problems. I think this is largely because there was no one at Dartmouth responsible for it or willing to take it on. It would have been helpful to have, especially if there had been interactive classification capability (I don't believe there is even now.)

V. Field Work

A. Visits to the Field. Gibb Dodge, Ken Sutherland, Kevin Doran, and I made numerous visits both on the ground and in the air, to areas we classified. Some of the trips were:

To Second Connecticut Lake and Dartmouth College Grant (northern NH) to look at spruce-fir and hardwood areas.

To Christine Lake, South Ponds, Dummer, Stratford Bog, Nash Bog, and Indian Stream (all in northern NH) to look at clearcuts.

To northern Maine to look at the Seven Islands project applications area and at the spruce budworm infestation.

B. Aerial photos. We had aerial photos of the following areas flown to use as ground truth (all were color 9" by 9" format).

Second Connecticut Lake (northern NH)

Dartmouth College Grant (northern NH)

Stratford Bog, South Ponds, and vicinity (northern NH)

Gale River (northern NH)

Andorra Forest, Fox Forest, Pillsbury State Forest (southwestern NH)

Calvin Coolidge State Forest (middle - eastern VT)

Babbitt Hill (Lisbon, NH)

Cherry Ponds (northwestern NH)

C. Field Plots. About 400 forestry field plots total were taken to check classification categories. These included tallies of density, size, and species of trees on a 1/10 acre prism plot. The areas were Second Connecticut Lake, Dartmouth College Grant, and Babbitt Hill. Plots were located on printouts, and then classification categories compared with plot tallies.

VI. Communications with the Outside World

A. Publications. The forestry group has published or presented 11 papers. the Journal of Forestry article and the article in Photogrammetric Engineering and Remote Sensing magazine seem most important to me. A list of publications is in Appendix E. Some reprints are also provided (Appendix F).

B. Conferences Attended.

LARS symposium on Machine Processing of Remotely Sensed Data: Em attended in 1975, Gibb and Em attended in 1976 and presented a short paper, and Kevin attended and gave a short paper in 1981.

ERIM Symposium on Remote Sensing of Environment: 11th (1977) -- Gibb and Em attended; 13th (1979) -- Gibb, Em, and Ken attended and gave a poster paper; 15th (1981) -- Em and Steve Ungar gave a poster paper.

National Workshop on Integrated Inventories of Renewable Natural Resources, Tucson, AZ, Jan., 1978. Gibb, Em, and Sam Warren of Seven Islands Land Company attended and presented the Seven Islands paper.

RSGNNE (Remote Sensing Group of Northern New England). Gibb and/or Em attended this every year and presented a paper once or twice.

National Workshop on In-Place Resource Inventories, Orono, ME, Aug, 1981. Em attended this.

Northeastern Regional Conference on Landsat, Storrs, Conn., Nov., 1975. Gibb, Em, and others attended this.

Meeting of the Classification Society, Rochester, NY, May, 1976. Em and Gibb attended and presented a paper.

C. Classes and Talks Given. Gibb and/or Em gave guest lectures in remote sensing classes about three times at UNH and about eight times at Dartmouth. This usually consisted of a description of how classification of Landsat data works, and of an applications project.

Talks were also given to the NH section of the Society of American Foresters, the Grafton County Soil Conservation District, the Squam Lakes Science Center, and others.

D. Dartmouth Remote Sensing Meetings. These meetings were held sporadically (more or less once a month, from 1979 to 1982) and were mostly a means for everyone working on the grant to sit down in the same room and chat. A short talk was given each time, occaisionally by an outside speaker , such as from CRREL or PIC. A final meeting was held in honor of the accomplishments of the grant, and about 20 to 30 people came from as far away as Boston and New York.

VII. Results and Impact of the Forestry Group

Gibb will have more to say on this, but I would like to make a few points:

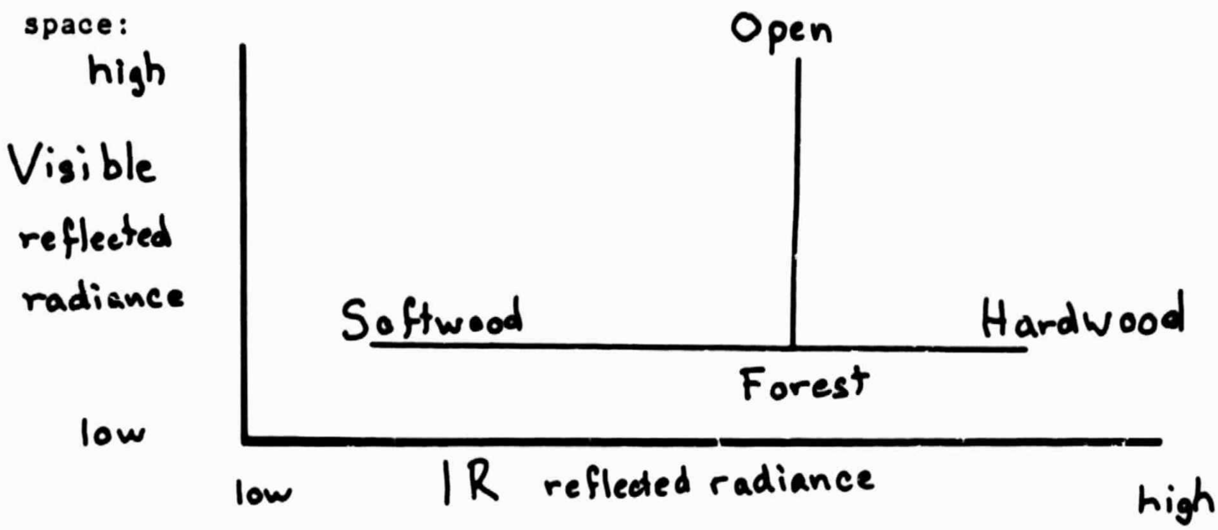
A. We found a good working combination for a research project -- that is, a practicing forester (Gibb), an applied research person (Em) supported by more theoretical researchers (at GISS). I think the key to success is having enough links in the chain of people from abstract researcher to field person. If there is mutual trust and respect between each link and their adjacent links, then the information can flow. If there isn't, it can't. For instance, I think that contacts with paper companies would have been minimal and less successful if Em had tried to initiate them instead of working through Gibb.

B. Education. Through the forestry group's efforts, a lot of people outside the group were educated about the capabilities of Landsat, and a lot of people inside the grant learned what a "pixel" is and how to classify it using the GISS system. There were about 100 people who worked in connection with the Grant over the past eight years.

C. Simple Approach. Throughout the years, the forestry group has generally taken on projects that were simple and straightforward (e.g. mapping softwood and hardwood) rather than attacking the more intricate things (e.g. determining density). There always seemed to be more useful information to be gotten with less effort using this approach. Thus some relevant lines of research were not pursued very far or were not done successfully because they were judged to be too elaborate. These can be left to the big research outfits with their hoardes of people and fancy computers. I think we got quite a bit accomplished, considering that there was usually no more than the equivalent of two full-time people working on the project at any one time.

IX. Conclusions

For detailed, specific conclusions, see the project summaries in sectins I, II, and III, or the individual write-ups of projects. A gross, overall conclusion can be expressed in a single graph of what New England forests look like in color space:



To say it in words, you can map forests in New England using Landsat. The basic distinctions you can make are between softwood and hardwoods (and mixtures) and between forested land and open land (and stages in between). I hope to write this up in the MADSIG paper. Perhaps this generalized picture of the New England Vegetation has something to do with Kauth and Thomas's Tasseled Cap phenomenon. (LARS 1976, I believe)

IX. Recommendations

Over the past eight or 10 years, many people have worked painstakingly on such things as development of classification techniques, evaluation of classification algorithms, and determination of pixel - by - pixel accuracy of classification categories. This includes the forestry and geology groups at Dartmouth, people at GISS, and people in other research projects around the country and the world (e.g.LARS, ERIM). It seems to me that we may now be at the point where we have found out a lot of the basic capabilities of Landsat, and should start putting them together in a form that can be used easily, efficiently, and in combination with other kinds of information. New technologies such as array processors and fancy graphics devices make this more feasible.

Specific recommendatins for the GISS system follow (bear in mind that free advice is worth what you pay for it !)

1) If the system with its unique algorithm is worth preserving, it should be redesigned from the top down. Right now there are patches upon patches, which people don't understand because they were put on by a programmer three generations ago.

2) Create a comprehensive written user manual for the system. Right now, I believe the user manual resides in the brains of a combination of people. There is no single source of information on how to use it. The documentation should include a definitive description of the classification algorithm.

3) Freeze the system and package it so that others can acquire it and put it on their systems.

4) Incorporate in the system a program such as OPTIMIZE or DE TAS, which allows the person creating signatures to base their optimization of classification parameters on statistics developed

from training sites. This would make the classification procedure more rational and scientific instead of a blind magic act. The GISS algorithm requires this more than some less sophisticated algorithms (such as the parallelepiped algorithm) because the unaided user's brain cannot comprehend how the algorithm will behave when parameters are adjusted.

5) Another way of improving the process of developing classifications would be making it interactive. The Ramtek perhaps could be used, including use of the track ball to select training sites, feed them into an OPTIMIZE - like program and come out with a preliminary classification, without the user's having to know what the signatures or delmax values are. Fine tuning of the classification could also be interactive.

6) Landsat information will be most useful if it can be plugged in to other forms of information -- it will need some way of converting pixel coordinates to other coordinates automatically (e.g. the REGISTER program described in Section III.)

One final exhortation on the general trend of things: When Landsat 4 and SPOT data become available and/or when the use of remote sensing data becomes operational, there will be a lot more data to handle. When this happens, we will have to turn our attention away from research and development of details of Landsat capabilities, and focus on application of the best results of the research and development in an operational way.

Then we can create geographic information that serves people's needs.

Appendix A1 -- SIGPACK Listing

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 .   wse sispack
MAND ? 1
1.      *** GRANT SIGNATURES. LINES 8-24. THESE SIGNATURES WERE DEVELOPED FOR
2.      LANDSAT DATA OF JULY 24, 1973, SCNID 1366-15060, PATH 14, ROW 29.
3.      THEY WERE USED IN THE CLASSIFICATION OF COOS AND CHESHIRE
4.      COUNTIES IN NEW HAMPSHIRE. THIS CLASSIFICATION IS DESCRIBED
5.      IN THE ARTICLE BY DODGE AND BRYANT, "FOREST TYPE MAPPING
6.      WITH SATELLITE DATA" IN THE AUGUST, 1976 ISSUE OF THE JOURNAL
7.      OF FORESTRY
7.5                              E. BRYANT, 26 MAR. 1980.
7.55
7.6       SAMPLE RUN : GRANT
7.65    GISS TAPES: A0079 (GEOCOR); A00526 (UNCORRECTED)
7.7       SCNID='1366-150600',GEOCOR=T
7.8       ULHC=450,2700,SIZE=200,200
8.        NUMSIG=7
9.        WBRT=7*.1
0.        DELMAX=.8,.045,.04,.04,.04,.07,.07
1.        SIG01=.29,.12,.06,.07
2.        NAME01='WATER'
3.        SIG02=.43,.2,.45,1.32
4.        NAME02='SOFTWOOD'
5.        SIG03=.42,.2,.53,1.61
6.        NAME03='SOFTWOOD'
7.        SIG04=.44,.2,.65,2.04
8.        NAME04='S-H'
9.        SIG05=.44,.2,.74,2.47
0.        NAME05='H-S'
1.        SIG06=.43,.21,.89,3.2
2.        NAME06='HARDWOOD'
3.        SIG07=.53,.33,.74,2.3
4.        NAME07='FIELD'
5.
6.      ***RUN 13. LINES 38-91.  THESE SIGNATURES WERE DEVELOPED FOR THE LANDSAT DATA
7.      OF JUNE 26,1975, SCNID 5068-14433, PATH 14, ROW 29 (NORTHERN NH)
8.      WE WERE TRYING TO DISCRIMINATE CLEARCUTS IN VARIOUS STAGES OF REGROWTH, AND
8.5     THUS EMPHASIZED THE VISIBLE
9.      BANDS WITH THE WBND AND BCONST CARDS, SINCE THAT IS WHERE THE DIFFERENCE
0.      SEEMED TO LIE.  THESE SIGNATURES WORK PRETTY WELL UNALTERED ON
1.      THE LANDSAT DATA OF JULY 24, 1973, SCNID 1366-15060 (THE ATMOSPHERES
2.      ON THOSE TWO DAYS MUST HAVE BEEN QUITE SIMILAR)
3.      RESULTS ON CLASSIFICATION OF CLEARCUTS USING THESE SIGNATURES ARE
4.      DESCRIBED IN A POSTER PAPER GIVEN AT THE 13TH ERIM SYMPOSIUM
5.      AUTHORED BY BRYANT, DODGE, AND EGER, ENTITLED "SMALL FOREST
6.      CUTTINGS MAPPED WITH LANDSAT DIGITAL DATA" (PROCEEDINGS, VOL. 2, P 971-981).
6.5                                           E. BRYANT, 26 MAR. 1980
7.
7.1     SAMPLE RUN:POND OF SAFETY
7.15    GISS TAPES:A00113 (GEOCOR); A01427 (UNCORRECTED)
7.2       SCNID='5068-144330',GEOCOR=T
7.3       ULHC=1249,2694,SIZE=86,106
8.        WBND=7.96,5.528,3.317,1.0,BCONST=-1.974,.293,-.335,0.0
9.        NUMSIG=24
0.        WBRT=20*.1,.5,.5,.1,.1
1.        DELMAX=.145,.125,.119,.111,.099,.085,.1,.09,.09,.08,.09,
2.          .122,.09,.075,.065,.063,.065,.065,.07,.07,.5,.18,.24,.09
3.        NUMSYM='  ...:.//FS@@OOO@OFFWLL*',OPRINT='        OO...O.    '
4.        SIG01=3.28,3.28,1.59,1.31
5.        NAME01='OPENBARE'
6.        SIG02=2.96,2.78,1.66,1.56
7.        NAME02='OPENBARE'
8.        SIG03=2.8,2.5,2.05,1.99
9.        NAME03='OPEN VEG'
0.        SIG04=2.64,2.23,2.48,2.42
1.        NAME04='OPEN VEG'
```

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```
     NAME05='OPEN VEG'
     SIG06=2.24,1.62,3.28,3.28
     NAME06='OLD CC'
     SIG07=1.91,2.21,2.01,2.04
     NAME07='OPEN VEG'
     SIG08=1.71,1.99,1.39,1.46
     NAME08='S CC'
     SIG09=1.67,2.0,1.2,1.2
     NAME09='S CC'
     SIG10=1.6,1.77,1.96,1.9
     NAME10='FRINGE'
     SIG11=1.49,1.54,1.08,1.17
     NAME11='SHORE'
     SIG12=1.29,1.29,1.29,1.29
     NAME12='SOFTWOOD'
     SIG13=1.33,1.3,1.66,1.76
     NAME13='SOFTWOOD'
     SIG14=1.37,1.32,2.04,2.23
     NAME14='MIXED'
     SIG15=1.41,1.33,2.41,2.7
     NAME15='HARDWOOD'
     SIG16=1.45,1.34,2.78,3.17
     NAME16='HARDWOOD'
     SIG17=1.14,1.43,1.83,2.04
     NAME17='SOFTWOOD'
     SIG18=1.14,1.34,2.42,2.77
     NAME18='MIXED'
     SIG19=1.757,1.68,2.0,2.35
     NAME19='FRINGE'
     SIG20=1.757,1.4,2.51,3.1
     NAME20='FRINGE'
     SIG21=.97,1.18,.09,.15
     NAME21='WATER'
     SIG22=2.220,2.130,.650,.500
     NAME22='LEDGE'
     SIG23=1.135,1.425,.952,1.168
     NAME23='LEDGE'
     SIG24=1.68,1.47,3.46,3.61
     NAME24='OLDER CC'

   *** RUN 41. LINES 107-141  THESE SIGNATURES WERE DEVELOPED FOR LANDSAT DATA
   OF AUGUST 11, 1976, SCNID 5480-14043(PATH 12 ROW 28) IN MAINE
   THEY WERE USED IN THE CLASSIFICATION OF THE ASHLAND DISTRICT;
   AN AREA OF ABOUT 1/2 MILLION ACRES THAT THE SEVEN ISLANDS LAND
   COMPANY MANAGES. THIS IS DESCRIBED IN THE PAPER "SATELLITES
   FOR PRACTICAL NATURAL RESOURCE MAPPING? A TEST CASE" IN THE
   PROCEEDINGS OF THE WORKSHOP ON INTEGRATED INVENTORIES OF
   RENEWABLE NATURAL RESOURCES, TUCSON, ARIZONA, JANUARY, 1978,
   BY BRYANT, DODGE, AND WARREN.  A REVISION OF THIS PAPER IS
   BEING SUBMITTED TO TPHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING.
   THE SECOND INFRARED BAND WAS CANCELED OUT BECAUSE I THOUGHT IT HAD
   SIGNIFICANT RADIOMETRIC STRIPING; THE FIRST INFRARED BAND WAS
   WEIGHTED TO COMPENSATE FOR THE LOSS OF THE SECOND ONE.
                                              E. BRYANT, 26 MAR. 1980

   SAMPLE RUN: T8 R10
   GISS TAPES: P12 R27: A00120 (GEOCOR); A02854 (UNCORRECTED)
               P27 R 28: A00139 (GEOCOR); A02819 (UNCORRECTED)
     SCNID='5480-140430',GEOCOR=T
     ULHC=874,1110,SIZE=165,200
     NUMSIG=15
     WBRT=15*.1
     NUMSYM='   XXXOO++VVGW//',OPRINT='   OOO    __  W'
     WBND=1.0,1.0,3.98,0.0,BCONST=0.0,0.0,-.52,0.0
     DELMAX=.03,.03,.034,.050,.09,.12,.07,.07,.055,.035,.04,.04,.07,.65,.3
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A1-5

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3.     *** MJ'S 1975 SIGNATURES. LINES 174-190.
3.1    SAMPLE RUN: BABBITT HILL
3.15   GISS TAPES: A00113 (GEOCOR); A01427 (UNCORRECTED)
3.2      SCNID='5068-144330',GEOCOR=T
3.3      ULHC=1737,1974,SIZE=110,250
4.       NUMSIG=7
4.5      NUMSYM='O*/ W.S',OPRINT=' OO       '
5.       WBRT=.06,.06,.06,.1,.1,.1,.1
6.       DELMAX=.052,.070,.049,.130,.5,.130,.15
7.       SIG01=.467,.212,.951,3.020
8.       NAME01='HARDWOOD'
9.       SIG02=.430,.198,.534,1.526
0.       NAME02='SOFTWOOD'
1.       SIG03=.442,.206,.703,2.044
2.       NAME03='MIXED'
3.       SIG04=.774,.594,.710,1.869
4.       NAME04='BR FIELD'
5.       SIG05=.361,.152,.133,.168
6.       NAME05='LK WATER'
7.       SIG06=.486,.255,.594,1.693
8.       NAME06='DK FIELD'
9.       SIG07=.485,.286,.516,1.299
0.       NAME07='R WATER'
1.
2.     *** MJ'S AUGUST, 1976 SIGNATURES. LINES 196-213. THESE SIGNATURES WERE DEVELO
3.     LANDSAT DATA OF AUGUST 22, 1976, SCNID 2578-14463, PATH 14, ROW 29.
4.     LIKE THE SIGNATURE PACKAGES ABOVE, THEY WERE MADE FROM THE SAME TRAINING SITE
4.5                                        E. BRYANT, 16 APR 1980
5.
5.1    SAMPLE RUN:BABBITT HILL
5.15   GISS TAPES: A02437 (GEOCOR); A01257 (UNCORRECTED)
5.2      SCNID='2578-144630',GEOCOR=T
5.3      ULHC=1853,1731, SIZE=118,129
6.       NUMSIG=7
7.       WBRT=.06,.06,.06,.1,.1,.1,.1
8.       DELMAX=.054,.054,.042,.125,.480,.130,.110
9.       NUMSYM='O*/ W.S',OPRINT=' OO       '
0.       SIG01=.393,.233,.737,2.114
1.       NAME01='HARDWOOD'
2.       SIG02=.381,.221,.462,1.15
3.       NAME02='SOFTWOOD'
4.       SIG03=.4,.236,.578,1.535
5.       NAME03='MIXED'
6.       SIG04=.483,.325,.705,1.857
7.       NAME04='FIELDS'
8.       SIG05=.324,.189,.164,.211
9.       NAME05='LK WATER'
0.       SIG06=.637,.506,.579,1.206
1.       NAME06='B FIELD'
2.       SIG07=.397,.239,.384,.845
3.       NAME07='R WATER'
4.
5.     ***CHRIS HARRIS'S BABBITT HILL SIGNATURES LINES 222-243. DEVELOPED FOR DATA
6.     FROM 22 AUGUST 1976, SCNID 2578-14463, PATH 14, ROW 29.   .
7.     THESE SIGNATURES WERE MADE TO MATCH THOSE MJ MADE FOR
8.     JULY,1973 (SEE LINE154 ABOVE). A COUPLE OF NEW SIGNATURES WERE ADDED
9.     TO FILL IN AREAS THAT DIDN'T CLASSIFY WITH MJ'S TRAINING SITES.
0.     CHRIS WROTE UP THIS EXPERIMENT: SEE E. BRYANT FOR A COPY OF IT.
0.5                                    E. BRYANT, 10 APR, 1980
1.
1.1    SAMPLE RUN: BABBITT HILL
1.15   GISS TAPES: A02437 (GEOCOR); A01257 (UNCORRECTED)
1.2      SCNID='2578-144630',GEOCOR=T
1.3      ULHC=1850,1720, SIZE=129,265
2.       NUMSIG=9
3.       WBRT=5*.1,.2,3*.1
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```
3.      *** MJ'S 1975 SIGNATURES. LINES 174-190.
3.1     SAMPLE RUN: BABBITT HILL
3.15    GISS TAPES: A00113 (GEOCOR); A01427 (UNCORRECTED)
3.2       SCNID='5068-144330',GEOCOR=T
3.3       ULHC=1737,1974,SIZE=110,250
4.        NUMSIG=7
4.5       NUMSYM='O*/ W.S',OPRINT=' OO      '
5.        WBRT=.06,.06,.06,.1,.1,.1,.1
6.        DELMAX=.052,.070,.049,.130,.5,.130,.15
7.        SIG01=.467,.212,.951,3.020
8.        NAME01='HARDWOOD'
9.        SIG02=.430,.198,.534,1.526
0.        NAME02='SOFTWOOD'
1.        SIG03=.442,.206,.703,2.044
2.        NAME03='MIXED'
3.        SIG04=.774,.594,.710,1.869
4.        NAME04='BR FIELD'
5.        SIG05=.361,.152,.133,.168
6.        NAME05='LK WATER'
7.        SIG06=.486,.255,.594,1.693
8.        NAME06='DK FIELD'
9.        SIG07=.485,.286,.516,1.299
0.        NAME07='R WATER'
1.
2.      *** MJ'S AUGUST, 1976 SIGNATURES. LINES 196-213. THESE SIGNATURES WERE DEVELO
3.      LANDSAT DATA OF AUGUST 22, 1976, SCNID 2578-14463, PATH 14, ROW 29.
4.      LIKE THE SIGNATURE PACKAGES ABOVE, THEY WERE MADE FROM THE SAME TRAINING SITE
4.5                                          E. BRYANT, 16 APR 1980
5.
5.1     SAMPLE RUN:BABBITT HILL
5.15    GISS TAPES: A02437 (GEOCOR); A01257 (UNCORRECTED)
5.2       SCNID='2578-144630',GEOCOR=T
5.3       ULHC=1853,1731, SIZE=118,129
6.        NUMSIG=7
7.        WBRT=.06,.06,.06,.1,.1,.1,.1
8.        DELMAX=.054,.054,.042,.125,.480,.130,.110
9.        NUMSYM='O*/ W.S',OPRINT=' OO      '
0.        SIG01=.393,.233,.737,2.114
1.        NAME01='HARDWOOD'
2.        SIG02=.381,.221,.462,1.15
3.        NAME02='SOFTWOOD'
4.        SIG03=.4,.236,.578,1.535
5.        NAME03='MIXED'
6.        SIG04=.483,.325,.705,1.857
7.        NAME04='FIELDS'
8.        SIG05=.324,.189,.164,.211
9.        NAME05='LK WATER'
0.        SIG06=.637,.506,.579,1.206
1.        NAME06='B FIELD'
2.        SIG07=.397,.239,.384,.845
3.        NAME07='R WATER'
4.
5.      ***CHRIS HARRIS'S BABBITT HILL SIGNATURES LINES 222-243. DEVELOPED FOR DATA
6.      FROM 22 AUGUST 1976, SCNID 2578-14463, PATH 14, ROW 29.   .
7.      THESE SIGNATURES WERE MADE TO MATCH THOSE MJ MADE FOR
8.      JULY,1973 (SEE LINE154 ABOVE). A COUPLE OF NEW SIGNATURES WERE ADDED
9.      TO FILL IN AREAS THAT DIDN'T CLASSIFY WITH MJ'S TRAINING SITES.
0.      CHRIS WROTE UP THIS EXPERIMENT: SEE E. BRYANT FOR A COPY OF IT.
0.5                                    E. BRYANT, 10 APR, 1980
1.
1.1     SAMPLE RUN: BABBITT HILL
1.15    GISS TAPES: A02437 (GEOCOR); A01257 (UNCORRECTED)
1.2       SCNID='2578-144630',GEOCOR=T
1.3       ULHC=1850,1720, SIZE=129,265
2.        NUMSIG=9
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.       DELMAX=.045,.057,.057,.088,.070,.5,.08,.1,.2
. .   . NUMSYM=' OOOOWWU.',OPRINT='   @. /  '
.       SIG01=.475,.298,.690,1.779
.       NAME01='FIELD1'
.       SIG02=.38,.226,.723,1.967
.       NAME02='HARDWOOD'
.       SIG03=.381,.226,.732,2.373
.       NAME03='HARDWOOD'
.       SIG04=.38,.221,.46,1.143
.       NAME04='SOFTWOOD'
.       SIG05=.38,.224,.591,1.576
.       NAME05='MIXED'
.       SIG06=.324,.188,.165,.215
.       NAME06='WATER'
.       SIG07=.4,.24,.38,.85
.       NAME07='SHORE'
.       SIG08=.41,.235,.647,1.79
.       NAME08='URBAN'
.       SIG09=.531,.4,.528,1.18
.       NAME09='FIELD2'
.
.     *** SW NEW HAMPSHIRE SIGNATURES. LINES 251-268. THESE SIGNATURES WERE
.     DEVELOPED TO CLASSIFY LANDSAT DATA OF JULY 24, 1973, SCNID 1366-15063
.     PATH 14, ROW 30.  THEY WERE USED IN THE CLASSIFICATION OF CHESHIRE AND
.     SULLIVAN COUNTIES WHICH WAS WRITTEN UP IN THE JOURNAL OF FORESTRY
.     ARTICLE OF AUGUST,1976, "FOREST TYPE MAPPING WITH SATELLITE DATA".
.3    BY DODGE AND BRYANT.
.5                                  E. BRYANT, 10 APR 1980.
.
.01   SAMPLE RUN: PART OF FRANKLIN CO., MASS.
.05   GISS TAPES: A00080 (GEOCOR); A00527 (UNCORRECTED)
.1      SCNID='1366-150630',GEOCOR=T
.3      ULHC=2100,2200,SIZE=200,200
.       NUMSIG=7
.       WBRT=7*.1
.       DELMAX=.6,.048,.064,.08,.04,.07,.16
.       NUMSYM='WF X.F*',OPRINT='   O   '
.       SIG01=.37,.17,.13,.18
.       NAME01='WATER'
.       SIG02=.54,.3,.69,2.08
.       NAME02='FIELD'
.       SIG03=.44,.2,.84,2.95
.       NAME03='HARDWOOD'
.       SIG04=.43,.2,.56,1.64
.       NAME04='SOFTWOOD'
.       SIG05=.44,.19,.67,2.29
.       NAME05='MIXED'
.       SIG06=.54,.3,.69,2.08
.       NAME06='FIELD'
.       SIG07=.41,.21,.4,1.15
.       NAME07='SHORELINE'
.
.     *** MADISON SIGNATURES. LINES 276-303. THESE SIGNATURES WERE DEVELOPED FOR
.     LANDSAT DATA OF JULY 23, 1973, SCNID 1365-15004, PATH 13, ROW 30. THEY WERE
.     ADJUSTED TO MATCH ACREAGE FIGURES MEASURED FROM COLIN SUTHERLANDS FOREST TYPE
.     MAP OF THE TOWN OF MADISON, NH. SEE E. BRYANT FOR A WRITE-UP OF THIS
.     PROJECT.
.5                                 E. BRYANT 10 APR, 1980
.
.1    SAMPLE RUN: MADISON, NH
.15   GISS TAPES: A00183 (GEOCOR); A00525 (UNCORRECTED)
.2      SCNID='1365-150040' GEOCOR=T
.3      ULHC=61,1340,SIZE=210,200
.       NUMSIG=12
.       WBRT=12*.1
.       NUMSYM='..:!@/.OOO //',OPRINT='    OOO       '
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7.        DELMAX=.12,.09,.09,.058,.084,.085,.047,.05,.08,.07,.8,.1
0. .    . SIG01=.9,.74,.8,2.0
1.        NAME01='OPENBARE'
2.        SIG02=.78,.6,.78,2.1
3.        NAME02='OPENBARE'
4.        SIG03=.65,.47,.76,2.2
5.        NAME03='OPEN VEG'
6.        SIG04=.53,.33,.74,2.3
7.        NAME04='OPEN VEG'
8.        SIG05=.43,.2,.45,1.32
9.        NAME05='SOFTWOOD'
0.        SIG06=.43,.202,.538,1.696
1.        NAME06='S-H'
2.        SIG07=.43,.204,.626,2.072
3.        NAME07='H-S'
4.        SIG08=.43,.206,.714,2.448
5.        NAME08='HARDWOOD'
6.        SIG09=.43,.208,.802,2.824
7.        NAME09='HARDWOOD'
8.        SIG10=.43,.21,.89,3.2
9.        NAME10='HARDWOOD'
0.        SIG11=.29,.12,.06,.07
1.        NAME11='WATER'
2.        SIG12=.35,.16,.35,1.05
3.        NAME12='SHORE'
4.
5.      *** SHOTGUN SUPERVISED. LINES 317-375. THIS IS A CRAZY SIGNATURE
6.      PACKAGE WHICH IS DESIGNED TO CLASSIFY SUMMER VEGETATED AREAS FROM
7.      MOST ANY DATA (IN THE SUMMER) -- THE CATEGORIES INCLUDED IN IT WILL
8.      CLASSIFY MOST OF THE RANGE OF ENERGIES ENCOUNTERED IN SUMMER DATA
9.      IN MY EXPERIENCE..  FOR INSTANCE, SOFTWOOD MAY COME OUT AS DIFFERENT
0.      CATEGORIES IN AN AUGUST, 1976 PASS THAN IN A JULY, 1973 PASS, BUT IT
1.      GENERALLY WILL COME OUT AS SOME CATEGORY. THERE ARE ALSO USUALLY
2.      ENOUGH CATEGORIES CLASSIFIED TO IDENTIFY SHAPES AND LOCATE FEATURES.
3.      THIS IS KIND OF A SUBSTITUTE FOR A GRAY SCALE OR UNSUPERVISED
4.      CLASSIFICATION, WITH THE ADVANTAGE THAT THE CATEGORIES WON'T
5.      CHANGE FROM ONE AREA TO ANOHER ON THE SAME PASS.
5.1     SEE E. BRYANT FOR A WRITE-UP OF THIS.
5.2                                    E. BRYANT 16 APR 1980
6.
6.1     SAMPLE RUN: STRATFORD BOG, 26 JUN '75
6.15    GISS TAPES: A00113 (GEOCOR); A01427 (UNCORRECTED)
6.2       SCNID='5068-144330',GEOCOR=T
6.3       ULHC=900,2355,SIZE=64,80
7.        NUMSIG=26
8.        WBRT=26*.1
9.        WBND=0.0,6.875,0.0,1.0,BCONST=0.0,-.4375,0.0,0.0
0.        DELMAX=.06,.063,.063,.065,.069,.065,.068,.076,.076,.068,.07,.083,
1.         .088,.083,.07,.09,.099,.099,.09,.11,.114,.11,.13,.13,.15,.8
2.        NUMSYM='EDC0C95B840A73956284173621W'
3.        OPRINT='  / // //  //  //  /          '
4.        SIG01=0.0,3.0,0.0,3.0
5.        NAME01='5HI 7HI'
6.        SIG02=0.0,2.45,0.0,3.0
7.        NAME02='5MH 7HI
8.        SIG03=0.0,3.0,0.0,2.45
9.        NAME03='5HI 7MH'
0.        SIG04=0.0,1.9,0.0,3.0
1.        NAME04='5MH 7HI'
2.        SIG05=0.0,2.45,0.0,2.45
3.        NAME05='5MH 7MH'
4.        SIG06=0.0,3.0,0.0,1.9
5.        NAME06='5HI 7M'
6.        SIG07=0.0,1.35,0.0,3.0
7.        NAME07='5ML 7HI'
          SIG08=0.0,1.8,0.0,2.45
```

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      NAME08='5M 7MH'
      SIG09=0.0,2.45,0.0,1.9
      NAME09='5MH 7M'
      SIG10=0.0,3.0,0.0,1.35
      NAME10='5HI 7ML'
      SIG11=0.0,.8,0.0,3.0
      NAME11='5LO 7HI'
      SIG12=0.0,1.35,0.0,2.45
      NAME12='5ML 7MH'
      SIG13=0.0,1.9,0.0,1.9
      NAME13='5M 7M'
      SIG14=0.0,2.45,0.0,1.35
      NAME14='5MH 7ML'
      SIG15=0.0,3.0,0.0,.8
      NAME15='5HI 7LO'
      SIG16=0.0,.8,0.0,2.45
      NAME16='5LO 7MH'
      SIG17=0.0,1.35,0.0,1.9
      NAME17='5ML 7M'
      SIG18=0.0,1.9,0.0,1.35
      NAME18='5M 7ML'
      SIG19=0.0,2.45,0.0,.8
      NAME19='5MH 7LO'
      SIG20=0.0,.8,0.0,1.9
      NAME20='5LO 7ML'
      SIG21=0.0,1.35,0.0,1.35
      NAME21='5ML 7ML'
      SIG22=0.0,1.9,0.0,.8
      NAME22='5M 7LO'
      SIG23=0.0,.8,0.0,1.35
      NAME23='5LO 7ML'
      SIG24=0.0,1.35,0.0,.8
      NAME24='5ML 7LO'
      SIG25=0.0,.8,0.0,.8
      NAME25='5LO 7LO'
      SIG26=0.0,2.0,0.0,.07
      NAME26='WATER'

    *** GRANT FOR JUNE, 76. LINES 459-475. MADE FOR SATELLITEE DATA OF
    JUNE 26, 1975, SCNID 5068-14433, PATH 14, ROW 29. THESE SIGNATURES HAVE
    THE SAME CATEGORIES AS THE SIGNATURES ABOVE MADE FOR THE GRANT
    IN JULY,1973.
                                  E. BRYANT 16 APR 1980

    SAMPLE RUN: GRANT
    GISS TAPES: A00113 (GEOCOR); A01427 (UNCORRECTED)
      SCNID='5068-144330',GEOCOR=T
      ULHC=500,2850,SIZE=150,150
      NUMSIG=7
      WBRT=7*.1
      DELMAX=.3,.042,.084,.06,.034,.09,.018
      SIG01=.37,.16,.13,.15
      NAME01='WATER'
      SIG02=.41,.18,.49,1.25
      NAME02='SUPER S'
      SIG03=.42,.19,.55,1.43
      NAME03='SOFTWOOD'
      SIG04=.44,.19,.65,1.99
      NAME04='S-H'
      SIG05=.43,.18,.85,2.75
      NAME05='H-S'
      SIG06=.43,.19,.94,3.17
      NAME06='HARDWOOD'
      SIG07=.54,.34,.73,2.04
      NAME07='FIELD'
```

```
477.     ***DELTAS RUN 4, 4TH REVISION. LINES 491-517. THESE SIGS WRE DEVELOPED FOR
478.     LANDSAT PASS OF AUGUST 11, 1976, PATH 12 ROW 28, NORTHERN MAINE
479.     SCNID 5480-14043.  THEY WERE MADE TO TEST HOW USEFUL THE DELTAS
480.     PROGRAM ON DTSS COULD BE IN DEVELOPING SIGNATURES. THE PROGRAM
481.     WAS A HELP IN THE INITIAL RUNS, BUT THE USER STILL HAS TO DEPEND ON
482.     TRIAL AND ERROR TO FINE TUNE THE CLASSIFICATION TO MATCH GIVEN
483.     GROUND TRUTH ACREAGES. THE DELTAS APPLICATION PROJECT IS PRETTY
484.     WELL DOCUMENTED -- SEE E. BRYANT FOR A WRITE-UP.
485.                                     E. BRYANT  25 JUNE 1980
486.
487.     SAMPLE RUN: T8 R10 (POLYGON NOT INCLUDED)
488.     GISS TAPES: P12 R 27: A00120 (GEOCOR); A02854 (UNCORRECTED
489.                 P12 R28: A00139 (GEOCOR); A02819 (UNCORRECTED)
490.
491.       SCNID='5480-140430',GEOCOR=T
492.       ULHC=874,1110,SIZE=165,200
493.       NUMSIG=10
494.       WBRT=.21,.376,.351,.036,.066,.119,.407,.376,.12,.409
495.       DELMAX=.12,.105,.116,.061,.086,.064,.041,.052,.045,.7
496.       NUMSYM=' @XOOOV".W'
497.       OPRINT=' OO ."_-  '
498.       SIG01=.482,.346,.376,.895
499.       NAME01='CC-ROAD'
500.       SIG02=.366,.16,.254,.582
501.       NAME02='SUPER-S'
502.       SIG03=.375,.164,.325,.851
503.       NAME03='SOFTWOOD'
504.       SIG04=.39,.18,.647,1.987
505.       NAME04='HARDWOOD'
506.       SIG05=.385,.175,.540,1.608
507.       NAME05='HS-RAT'
508.       SIG06=.38,.169,.432,1.23
509.       NAME06='SH-RAT'
510.       SIG07=.508,.323,.702,1.801
511.       NAME07='BOG E'
512.       SIG08=.448,.25,.646,1.684
513.       NAME08='BOG M'
514.       SIG09=.451,.223,.643,1.741
515.       NAME09='CUTOVER'
516.       SIG10=.314,.116,.074,.071
517.       NAME10='WATER'
518.
519.     ***SUP,FAN RUN 8. LINES 533-551. THESE SIGS WERE DEVELOPED FOR LANDSAT
520.     PASSES OF AUGUST 11,1976, PATH 12 ROWS 27 AND 28,
521.     SCNIDS 5480-14040 AND 5480-14043.  THEY WERE MADE TO
522.     SELECT THE WATER AND OPEN AREAS FROM THE CLASSIFICATION, LEAVING THE
523.     UNCLASSIFIED AS FOREST TO BE PASSED ON TO LEVEL
524.     2 TO HAVE THE FANNING ALGORITHM APPLIED.WATER IS 11% UNDER GROUND TRUTH
525.     ACREAGE, BUT THE OPEN AREA IS CLOSER IF ALDERS ARE COUNTED AS FOREST.
526.     MORE ON TEHE FAN PART OF THE CLASSIFICATION LATER.
527.     SEE E. BRYANT FOR A PRELIMUINARY DESCRIPTION OF THE PROJECT
528.
529.     SAMPLE RUN: T8 R10 (POLYGON NOT INCLUDED)
530.     GISS TAPES: P12 R27:A00120 (GEOCOR); A02854 (UNCORRECTED)
531.                 P12 R 28: A00139 (GEOCOR); A02819(UNCORRECTED)
532.
533.       SCNID='5480-140430',GEOCOR=T
534.       ULHC=874,1110,SIZE=165,200
535.       NUMSIG=6
536.       WBRT=.21,.148,.407,.299,.409,.429
537.       DELMAX=.109,.027,.041,.026,.422,.2
538.       NUMSYM=' .V"WS'
539.       OPRINT='  _-   '
540.       SIG01=.482,.346,.376,.895
541.       NAME01='CC-ROAD'
542.       SIG02=.451,.223,.643,1.741
```

```
   NAME02='CUTOVER'
 . SIG03=.508,.323,.702,1.801
   NAME03='BOG-E'
   SIG04=.448,.25,.646,1.684
   NAME04='BOG-M'
   SIG05=.314,.116,.074,.071
   NAME05='WATER'
   SIG06=.34,.138,.164,.327
   NAME06='SHORELINE'
*** DEER YARD SIGNATURES. LINES 558-571. MARK HEUBERGER
DEVELOPED THESE SIGNATURES TO MAP DEER YARDS IN SOUTHERN
NH ON LANDSAT PASS 30097-14545, JUNE 10,1978. TAPE NUMBER
IS A02217 (GEOCOR=T).
   SCNID='30097-145450',GEOCOR=T
   ULHC=750,1775,SIZE=250,250
   NUMSIG=5
   SIG01=.326,.166,.393,1.179
   SIG02=.495,.33,.483,1.297
   SIG03=.373,.183,.903,3.019
   SIG04=.372,.178,.715,2.271
   SIG05=.324,.174,.146,.28
   NAME01='SOFTWOOD'
   NAME02='OPEN'
   NAME03='HARDWOOD'
   NAME04='MIXEDWOOD'
   NAME05='WATER'
   WBRT=.1,.129,.311,.174,.460
   DELMAX=.15,.2,.065,.071,.438
   NUMSYM='O OOW',OPRINT='@  . '
*** GROVETON SIGNATURES LINES 574-622.
THIS FILE CONTAINS THE SIGNATURES THAT KEN USES ON THE
GROVETON LANDS (NASH BOG AREA) ON JUNE 10,1978 DATA
   NUMSYM='  ...:./'FWO.00...FFW*',OPRINT='            /@O  OOO    '
   WBND=8.475,7.871,3.643,1.073,BCONST=-1.58,-.049,-.308,-.058
   DELMAX=.145,.125,.119,.111,.099,.085,.1,.09,.09,.08,.09,
     .147,.010,.075,.063,.15,.065,.065,.07,.07,.4,.09
   NUMSIG=22,WBRT=22*.1
   SIG01=3.28,3.28,1.59,1.31
   SIG02=2.96,2.78,1.66,1.56
   SIG03=2.8,2.5,2.05,1.99
   SIG04=2.64,2.23,2.48,2.42
   SIG05=2.4,1.9,2.88,2.85
   SIG06=2.24,1.62,3.28,3.28
   SIG07=1.91,2.21,2.01,2.04
   SIG08=1.71,1.99,1.39,1.46
   SIG09=1.67,2.0,1.2,1.2
   SIG10=1.6,1.77,1.96,1.9
   SIG11=1.49,1.54,1.08,1.17
   SIG12=1.29,1.29,1.29,1.29
   SIG13=1.37,1.32,2.04,2.23
   SIG14=1.41,1.33,2.41,2.7
   SIG15=1.45,1.34,2.78,3.17
   SIG16=1.33,1.3,1.66,1.76
   SIG17=1.14,1.43,1.83,2.04
   SIG18=1.14,1.34,2.42,2.77
   SIG19=1.757,1.68,2.0,2.35
   SIG20=1.757,1.4,2.51,3.1
   SIG21=.97,1.18,.09,.15
   SIG22=1.68,1.47,3.46,3.61
   NAME01='OPENBARE'
   NAME02='OPENBARE'
   NAME03='OPEN VEG'
   NAME04='OPEN VEG'
   NAME05='OPEN VEG'
   NAME06='OLD CC'
   NAME07='OPEN VEG'
```

```
608.     NAME08='SFTWD CC'
609.   , NAME09='SFTWD CC'
610.     NAME10='FRINGE'
611.     NAME11='WATER'
612.     NAME12='SOFT WD'
613.     NAME13='MIXED WD'
614.     NAME14='HARD WD'
615.     NAME15='HARD WD'
616.     NAME16='MIXED WD'
617.     NAME17='MIXED WD'
618.     NAME18='MIXED WD'
619.     NAME19='FRINGE'
620.     NAME20='FRINGE'
621.     NAME21='WATER'
622.     NAME22='OLDST CC'
623.   ***DEER YARD SIGNATURES. LINES 628-645. FEB. 1981
624.   THESE SIGNATURES ARE BASED ON MARK HEUBERGER'S SIGNATURES
625.   BUT AN ADDITIONAL VEGETATED OPEN SIGNATURE WAS ADDED.
626.   THE SIGNATURES WERE USED  TO MAP THE TOWNSHIPS OF UNITY
627.   AND ACWORTH.  SEE E. BRYANT FOR A WRITE-UP AND COPIES
627.1                          S. JOHNSON MAY 14,1981
628.     SCNID='30097-14545',GEOCOR=T
629.     ULHC=780,1500,SIZE=200,260
630.     NUMSIG = 6
631.     SIG01=.326,.166,.393,1.179
632.     SIG02 = .453,.253,.798,2.601
633.     SIG03=.495,.33,.483,1.297
634.     SIG04=.373,.183,.904,3.019
635.     SIG05=.372,.178,.715,2.271
636.     SIG06=.324,.174,.146,.28
637.     NAME01='SOFTWOOD'
638.     NAME02='OPEN'
639.     NAME03 = 'OLD OPEN'
640.     NAME04 = 'HARDWOOD'
641.     NAME05 = 'MIXEDWOOD'
642.     NAME06 = 'WATER'
643.     WBRT = .1,.17,.129,.311,.174,.460
644.     DELMAX = .15,.025,.2,.065,.071,.438
645.     NUMSYM='O..OOW',OPRINT = '@    . '
646.   *** BELKNAP COUNTY SIGNATURES. LINES 662 TO 691. THESE SIGS
647.   ARE BASED ON THE MADISON SIGNATURES BUT HAVE A FUDGE FACTOR
648.   BUILT IN TO MAKE THEM WORK ON DATA FROM JUNE 10,1978
649.   SOME SIGMNATURES HAVE BEEN MODIFIED AND THE BLUEBERRY OR LOW
650.   VEGETATION SIGNATURE HAS BEEN ADDED TO FIT WHAT TOM
651.   HADLEY (NORTH COUNTRY R C & D  PERSON) SAW AS THE RIGHT
652.   OR THE USEFUL CATEGORIES.
655.   THIS PACKAGE IS MEANT TO RUN ON DATA OF 10 JUN 1978
656.   PATH 14, ROWS 29 AND 30
657.   P 14, R29: SCNID 30097-14543, GISS TAPE:A01879 (UNCORRECTED),
658.        A02419 (GEOCOR)
659.   P 14, R 30: SCNID 30097-14545, GISS TAPE:A02303 (UNCORRECTED)
660.        A02217 (GEOCOR)
661.   SAMPLE RUN: THE NORTHERN TIP OF BELKNAP COUNTY.
662.     SCNID='30097-145430',GEOCOR=T
663.     ULHC=2050,1976,SIZE=85,500
664.     WBND=1.964,1.937,1.092,1.056,BCONST=-.275,-.168,-.034,-.113
665.     NUMSIG=11
666.     WBRT=11*.1
667.     NUMSYM='..::*OOOO /'
668.     OPRINT='     @ /.   '
669.     DELMAX=.12,.09,.09,.058,.036,.15,.068,.07,.08,.5,.3
670.     SIG01=.9,.74,.8,2.0
671.     NAME01='OPENBARE'
672.     SIG02=.78,.6,.78,2.1
673.     NAME02='OPENBARE'
674.     SIG03=.65,.47,.76,2.2
```

```
NAME03='OPEN VEG'
SIG04=.53,.33,.74,2.3
NAME04='OPEN VEG'
SIG05=.516,.254,.748,2.385
NAME05='B-BERRY'
SIG06=.43,.2,.45,1.32
NAME06='SOFTWOOD'
SIG07=.43,.21,.89,3.2
NAME07='HARDWOOD'
SIG08=.43,.203,.59[illegible],1.947
NAME08='S-H'
SIG09=.43,.207,.743,2.573
NAME09='H-S'
SIG10=.29,.12,.06,.07
NAME10='WATER'
SIG11=.35,.16,.35,1.05
NAME11='SHORE'
OMMAND ? ***
RE YOU STILL THERE?
OMMAND ? ***
ESPOND OR BE LOGGED OFF
OMMAND ? ***
ILTEN EXCPS = 1423
LAPSED TIME = 00:35:41
ND OF SESSION
ROP FROM MVT       041

1/370 ONLINE
```

APPENDIX B

FINAL REPORT AND COMMENTS (PART OF A JOINT REPORT)
APPLYING SATELLITE (LANDSAT) MEASUREMENTS TO
FOREST RESOURCE INVENTORIES
1974 - 1982

Background and Purpose

In 1974, New Hampshire Cooperative Extension Service, U.N.H. was asked to provide supportive services in forestry remote sensing to the Goddard Institute for Space Studies, New York, N.Y. through the Dartmouth College Earth Science Department. Since that time, supportive services have been provided in site selection, guidance, evaluation, collaboration, and informal education to potential users of landsat forestry data.

The purpose of the three-way working combination has been to blend basic research and applications experience and produce useful forestry information from landsat data. As the project progressed, the purpose was expanded to work with potential users through Cooperative Extension Service and Dartmouth to assure that we knew what data had potential in the field and to help potential users apply landsat forestry data in their field of endeavor. The principals in this program were:

Emily Bryant, Dartmouth College (1974-1982)
Arthur G. Dodge, Jr. (Gibb) Cooperative Extension Service, U.N.H. (1974-1982)
Kevin Doran, Cooperative Extension Service, U.N.H. (1980-1981)
Kenneth Sutherland, Jr., Cooperative Extension Service, U.N.H. (1979-1980)

Interaction between these people produced a unique combination of basic scientific research capability and informal education techniques which could be applied to assist field users of landsat forestry data. Applications of this data ranged from broad base forest type mapping to detecting, locating and measuring changes in forest cover and use.

Contacts Where Interchange of Ideas and Applications Occurred

During the project period, literally hundreds of people were involved with the program principals in attempting to adapt landsat forestry data to practical field use. It is impossible to list all individuals, but the following list of organizations is an indication of the magnitude of our efforts.

Bendix Corp.
Brown Co., Berlin, NH (Now James River Corp.)
Canadian Ctr. for Remote Sensing, Ottawa, CA
Canadian Forest Fire Research Institute
Cold Regions Lab, Hanover, NH
Cooperative Extension Service National Task Force on Remote Sensing
Fish and Game Dept., Concord, NH
Goddard Institute for Space Studies, New York, NY
Grafton City Soil Conservation District, Grafton County, NH
Granite State SAF
Great Northern Paper Co., Millinocket, ME
Groveton Papers (Dia Nat'l), Groveton, NH

Errsac, Goddard Space Flight Ctr.
International Paper Co., Jay, ME
Johnson Space Ctr., Houston, TX
Land Use Regulation Comm., Augusta, ME
New England Innovation Group
New England RC&D Representatives
New England - St. Lawrence Valley Geographical Association
N.H. Dept. of Resource and Economic Development, Concord, NH
NEARS, Boston, MA
Northeastern Cooperative Forestry Program Supervisors Representing 20 States
Office of State Planning, Concord, NH
Orser, Penn. State University, University Park, PA
Purdue University, Indiana
Remote Sensing Group of No. New England
St. Regis Paper Co., W. Stewartstown, NH and Jacksonville, FL
Seven Islands Land Co., Bangor, ME
Thayer School of Engineering, Dartmouth
Universities of Alaska, Columbia, New York, Massachusetts, Maine, Michigan, Missouri, New Hampshire, Rochester, NY, Vermont
U.S.F.S. State and Private, Portsmouth, NH
U.S.F.S. White Mountain National Forest
Wagner Woodlands, Lyme, NH

Results

In addition to scientific papers and presentations at professional meetings, seminars and workshops (Included elsewhere in this joint report), we helped to accomplish the following:

Pioneered the development of informal education techniques to help field users adapt landsat forestry data to their needs.

Recognition by the New Hampshire Office of State Planning that landsat remote sensing must be applied in New Hampshire.

Development of New Hampshire pilot project with Errsac, Goddard Space Flight Center, N.H. Office of State Planning and N.H. Fish and Game Department.

Trained seven New Hampshire state employees in the basics of landsat data processing and its use in natural resources.

Developing an operational system for N.H. Fish and Game Department to identify potential deer yarding areas.

Maine Land-Use Regulation Commission developed an operational forest type mapping system.

Produced a forest cover type map for Belknap County, NH

Trained four or five graduate students who are currently employed in natural resource fields and using landsat data on an operational basis.

Recommendations

1. With the advent of landsat D(4) remote sensing is at a critical point. Remote sensing scientists, educators and enthusiasts should encourage and lobby for the continued development of landsat mapping and interpretation techniques in both the public and private sector.

Unless a core of knowledgeable people is maintained there will be many "wheels reinvented" in future years. It is a known fact that practical knowledge and techniques which exist but are not continually used will soon disappear only to be rediscovered at a later date. The process of re-discovering is time consuming and economically wasteful. Practical landsat mapping applications must be maintained.

It is our hope that research organizations, private foundations and private industry will combine efforts to continue developing an operational satellite mapping system for use in forestry and natural resources. Thus filling a developing void that results from a diminishing public effort.

2. Emphasize the need for an operational landsat system capability being sustained within the continental United States. Aerial photos are becoming extremely expensive. All resource mapping activities will eventually have to depend on less expensive techniques. Unless satellite mapping systems are maintained within this country, we may not have them available when needed.

Acknowledgements:

Cooperative Extension Service, Cooperative Forestry Programs, U.N.H. greatfully acknowledges the cooperation of all faculty and staff at Dartmouth and GISS who have been involved with our joint effort. Special thanks and appreciation to Emily Bryant for her assistance, patience and willingness to work hard under a wide variety of situations. Without her willing participation, the results we list would not have been accomplished.

Arthur G. Dodge, Jr. (Gibb)
Program Leader
Forestry/CFM Supervisor
July, 1982

APPENDIX C

GIGI Show Manual

This manual describes the operation of the GIGI Show system, a program written for the Earth Sciences Department at Dartmouth under NASA NCC 5-22. The manual is a collection of the help information available from within the system. To get another copy of the manual, type OLD *p11332:MANUAL, and when it types Ready, you type BACK. This will generate a copy of the manual on the printer at Kiewit, where you then can pick it up. Further clarification can be obtained from:

Emily Bryant
RFD Box 481
Lyme Ctr., NH 03769
(603) 795-4409

Contents

General Help

"GIGI show " is a system used to display digital pictures on a DEC GIGI color screen terminal. It runs from commands. The most important commands are GET, which specifies the data file to be displayed, and PAINT, which displays the picture. The data must be in one of three formats. Type HELP FORMATS for details.

Other useful commands are COLOR (used to assign colors to data categories), and PUT (specifies where on the screen the picture is to be displayed).

For more details on these commands, type HELP followed by the command name. For a complete list of commands, type HELP COMMANDS. For information on the general structure of the system, type HELP SHOW.

****

Sample Session:
The symbols {} are used here to enclose what you type. Do not type them.

```
GG > {GET MAPFILE}

GG > {PUT LOWER LEFT}

GG > {COLOR OLD}

Which old color scheme ? {RAINBOW}

GG > {PAINT}

(At this point the picture requested is displayed in color on the screen).

GG >
```

****

file HELP.GEN

GIGI Show Files

The source code for the GIGI Show system is in the following files on user number P11332,MAPPIX :

File Name	Length (words)
GIGISHO7 (main)	6582
GETCOLOR	1601
GETPORT	193
HISTO	1318
MAPPER	3132
OWNPORT	355
PAINT6	2874
PARTI	981
UTILITY	780
WINDER	1175
XFTOGIGI	1803
Total	20794

Compiled version (takes about 25 CRU's to compile)
GIGI7.C 15050

Other files needed:

Libraries: PICLIB, COLORLIB (size varies with the number of entires)
Default picture data: GIGIHAN (1258 words)
HELP files: The names of the HELP files all begin with "HELP.".
Help files with the following suffixes currently exist:
HEL, SHO, FIL, COM, FOR, LEG, STA, WHA, CAT, GET, COL, PUT,
PAI, SAV, PUR, NEW, OLD, REN, STO, ERA, RES.

file HELP.FIL

The DEC GIGI color terminal

The GIGI terminal has some limitations which affect the quality of the display of picture data.

- There are only eight colors available: black, white, red, green, blue, cyan (blue plus green), magenta (red plus blue), and yellow (red plus green). There is no way to specify other colors or to combine these colors. This means that there are a maximum of eight distinct categories which can be displayed. This is why the GIGI Show system has to convert raw data to GIGI format data. It also means that you cannot, for instance, overlay data from one Landsat band (say, in red) with data from another Landsat band (say, in blue), to simulate a color composite. There are terminals which do this, in particular, the Ramtek at CRREL.

- The memory of the GIGI terminal is set up so that has quite fine resolution when it draws lines (240 pixels vertically by 767 horizontally), but it has significantly poorer resolution when it turns colors on (240 pixels vertically by 64 horizontally). A color block can have only one color at a time; so sometimes you will see colors that have already been drawn turn into other colors because an adjacent figure is drawn in another color. If this sounds complicated, it is. You can read more about it in the GIGI manuals. What it means here is that you get a really crude map, especially if the pixels in the data are close together.

- There is a means of filling the entire data pixel with the appropriate color instead of using the two characters O and X overlayed. This was not used in the GIGI show system because it seemed to be about four times slower than the current method. The filling sheme still has the problems of limited color resolution mentioned in the paragraph above.

file HELP.GIG

Suggestions for the GIGI Show System

The GIGI show system was written over a period of a month and a half, and would need more time or skill or something than that to be really robust, user-friendly, and all that, The hopes are that it will run reasonably well and that it is well enough documented and well enough structures that other people can modify and improve it over time. When modifications are made, I suggest that

- whoever makes them documents the changes and dates and signs them.
- always keep a copy of the source code of the most recently working version until you are sure that the next version works and is better.

Suggestions for improvements:

- Make a permanent library for Legends (like the ones for pictures and color schemes) and puit in the necessary CAT LEG (or whatever) command, so people can see what legends are saved.

- Make a library of data file names -- do not include the actual data in the library, because it would get too big -- then the names of the files that could be used in the GET command would be accessible from within the GIGI show system.

- Modify the PAINT6 subprogram so the user can specify which character is to be used to fill the pixels (right now it is always O superimposed on X).

There is undoubtedly more, but I'd better sign off now.

Emily Bryant
Nov. 23, 1982

file HELP.SUG

ORIGINAL PAGE IS
OF POOR QUALITY

GIGI Show and Current Pictures

A GIGI "show" is a collection of up to four "pictures" which are to be displayed on the DEC GIGI color screen terminal.
A "picture" consists of four (independent) components:

1) A picture name
2) A file of data in final GIGI format
3) A color scheme
4) A port (location on the screen)

A basic idea behind the GIGI Show system is that the "show" structure (consisting of up to four "pictures" each with four components) is always loaded and ready to be displayed at any "GG >" system prompt. When the system starts, the show is loaded with default values. System commands are provided so the user can revise the show to the values they want before (or after) they display it.

Assigning the revised values to the pictures is really a two-step procedure:

1) Establish a "current picture" which is to be revised, using the NEW or OLD command. The current picture is the only picture in the show whose values can be changed. There is exactly one current picture at any time. (There is a default current picture if the NEW or OLD command have not yet been given, but it is good practice always to use NEW or OLD before revising a picture.)

2) Revise any or all of the four components of the current picture:
- Picture name is revised by the RENAME command
- Data file is revised by the GET command
- Color scheme is revised by the COLOR command
- Port is revised by the PUT command

The four components of a picture are more or less independent, so they can be changed in any order. It is wise, however, to GET before you COLOR, because the program which assigns colors uses information from the data file about how many categories there are and what their names are.

In a GIGI show session, you can hop around from one picture to another and back to revise values; you do not have to make all changes to a picture at once. If you get confused about which picture is current, type WHAT. If you want to know what the current values are for all pictures in the show, type STATUS.

For further information on the commands mentioned above, type HELP followed by the command name.

File HELP.SHO

GIGI Show Data File Formats

There are currently three data formats which the GIGI Show system can handle:

1) Random access numeric
2) Standard raw data
3) Final GIGI

In all cases, the data is assumed to be associated with pixels which cover the area of the image, map, or whatever the data represents, in a regular rectangular grid. It assumes one datum per cell. (In other words, the four bands for raw Landsat data would either have to be handled separately in four individual files, or the data would have to have been classified already, with a result of only one category per pixel. Order of the data is assumed to be left to right, top to bottom (as you read).

1) Random access numeric. There is no header information in the file. Each record contains the datum for one cell.

2) Standard raw data format. This must be a terminal format file (TTY file).
   Line 1: Title for data.
   Line 2: "pixels.wide," width of picture in pixels
   Line 3: "pixels.high," height of picture in pixels
   Line 4: "pixel.shape," horizontal divided by vertical dimension of one pixel.
   Line 5: "file.type," either "characters" or "numbers", depending on the type of data.
   Data follows. Data is separated by commas or spaces or both; do not include commas or spaces within a character datum.

3) Final GIGI format. Same as standard raw data format, except:
   Line 5: "file.type, GIGI"
   Data follows. It is numeric integer data between 1 and 8 inclusive

One basic idea of the GIGI show system is that data to be displayed may come from varied sources -- Landsat, x-ray, digital land use maps, thermal scans, etc. These will probably be generated by different programs and will undoubtedly have different output formats. Rather than trying to anticipate all possible formats, GIGI Show defines one "standard raw data format". It is up to the person using the system to put their data in this format. The format puts certain restrictions on header information and order of data, but allows for character or numeric data, and any number of different data values. Before this can be displayed on the GIGI, however, the data must be reduced to a maximum of 8 numeric categories. The GIGI Show system does this when it asks for creation of a legend (Type HELP LEGEND for more details).

The ability to handle "random access numeric" format data is really an exception to the above rule of giving responsibility to the user to put their data in standard format. Since we happen to have four random access numeric files of Landsat data of the Hanover, NH area, and it is quite likely that this data will be used relatively frequently, the programming needed to convert this to standard raw data format has been incorporated into the system.

[illegible]

[illegible]
HELP [illegible] the GIGI show system
STATUS [illegible] pictures in the GIGI show
WHAT [illegible] picture
CAT [illegible] library specified (P1 [illegible] COLOR)

Picture [illegible]
NEW [illegible] tell the current picture.
OLD [illegible] in the show or picture library.
SAVE [illegible] picture in the picture library
PURGE [illegible] the show

Change [illigible]
GET [illegible] to the current picture
COLOR [illegible] current picture
PUT [illegible] location) to the current picture
RENAME [illegible] current picture

PAINT [illegible] picture or all pictures

System [illegible]
STOP [illegible]
ERASE [illegible] other effect)
RESET [illegible] restarts the GIGI show system from scratch.

file HELP.COM

HELP Commands

Format: HELP <modifier>
Where <modifier> currently can be any of the following:

- any command name: gives the format, explanation, and sample session for that command. (Type HELP COMMANDS for a list of commands.)
- HELP: gives the message you are now reading
- SHOW: explains the GIGI "show" and "picture" structures.
- FILES: lists the files needed to run the GIGI show system.
- COMMANDS: lists valid commands and what they do.
- FORMATS: explains the 3 valid data formats that GIGI show accepts.
- LEGEND: explains how the mapping from standard raw data to GIGI format proceeds.

<modifier> can always be abbreviated to its first three letters.

file HELP.HEL

STATUS Command

Format: STATUS

Explanation: The STATUS command lists the picture name, GIGI file name, color scheme, and port for each picture in the GIGI show. Useful when you are not sure what state the pictures are in. Status does not change the current picture or show. Type HELP SHOW for more information on pictures and shows.

****

Sample Session:
The symbols () are used here to enclose what you type. Do not type them.

```
GG > STATUS

Picture # 1 Name: bigmap
            GIGI file: GIGIMAP
            Colors: green yellow blue black black black black black
            Port: 0  1  0  1

Picture # 2 Name: biggermap
            GIGI file: GIGIHAN
            Colors: black blue red magenta green yellow cyan white
            Port: .3  .7  .2  .8

GG >
```

****

file HELP.STA

WHAT Command

Format: WHAT

Explanation: Prints out the name of the current picture. Useful when you are not sure which picture is current. (Type HELP SHOW for more information on current picture and show.) WHAT does not change anything in the show.

****

Sample Session:
The symbols {} are used here to enclose what you type. Do not type them.

```
GG > {WHAT}

Current picture is "default"

GG > {OLD bigmap}

GG > {WHAT}

Current picture is "bigmap"

GG >
```

****

file HELP.WHA

CAT Command

Format: CAT <catalog name>
where <catalog name is either PIC or COLOR>

Explanation: Lists the names of entries in a permanent library of GIGI Show -- either the picture library (PIC), which stores the specifications for pictures which have been saved previously, or the color library (COLOR) which stores color schemes stored previously.

****

Sample Session:
The symbols {} are used here to enclose what you type. Do not type them.

```
GG > {CAT PIC}

Catalog for PICLIB:
picturename, bigmap
picturename, HanoverNW
picturename, HanoverSE

GG > {CAT COLOR}

Catalog for COLORLIB:
rainbow
redscale
blues

GG >
```

****

file HELP.CAT

NEW Command

Format: NEW <new picture name>
Where <new picture name> represents a character string which has not already been used as the name of a picture in the current show.

Explanation: NEW is a request to establish a new picture in the GIGI show. It associates the name specified with one of the four places in the GIGI show (as long as there is one available). The new picture becomes the current picture. Type HELP SHOW for further information on "current picture" and "show".

Note: There is a default current picture, but it is good practice always to use the NEW or OLD command to set the current picture explicitly.

****

Sample Session:
(The symbols {} are used here to indicate what you type. Do not type them.)

```
GG > {WHAT}

Current picture is "default"

GG > {NEW bigmap}

GG > {WHAT}

Current picture is "bigmap"

GG >
```

****

file HELP.NEW

OLD Command

Format: OLD <old picture name>
where <old picture name> represents the name of a picture which is either in the current show or in the permanent picture library.

Explanation: The OLD command sets the current picture to be the one specified after "OLD". If this picture is not already present in the current GIGI show, it goes to the permanent picture library to find the picture specifications, and then establishes a spot for the picture in the show and loads the specifications from the library into the show.

Note: There is a default current picture, but it is good practice always to use either the OLD or the NEW command to establish the current picture explicitly rather than depending on the default.

****

Sample Session:

(The symbols {} are used here to indicate what you type. Do not type them.)

```
GG > {WHAT}

Current picture is "default"

GG > {OLD bigmap}

GG > {WHAT}

Current picture is "bigmap"

GG >
```

****

file HELP.OLD

SAVE Command

Format: SAVE
or SAVE <picture name>
Where <picture name> represents the name of a picture which is in the current show and not in the permanent picture library.

Explanation: Enters the specifications for a picture (that is, the picture name, GIGI file name, port, and color scheme) into a permanent picture library so they can be recalled at a subsequent time. The picture name is the key to the specifications; no duplicate picture names are allowed in the library. To find out what names are already in the library, type CAT PIC. If no picture name is specified in the SAVE command, the current picture is assumed. If a name is specified, you can save a picture that is not the current picture. If you do not know which picture is current, type WHAT before you type SAVE.

The SAVE command does not have any effect on the current picture or show. (Type HELP SHOW for further information on current picture and show.)

****

Sample Session:
(The symbols {} are used here to enclose what you type. Do not type them.)

```
GG > {CAT PIC}

Contents of PICLIB:

picturename, bigmap
picturename, biggermap

GG > {WHAT}

Current picture is "littlemap"

GG > {SAVE}

GG > {CAT PIC}

Contents of PICLIB:

picturename, bigmap
picturename, biggermap
picturename, littlemap

GG >
```

****

file HELP.SAV

PURGE Command

Format: PURGE
or PURGE <picture name>
where <picture name> represents the name of a picture in the current show.

Explanation: Removes the picture designated from the current show. Useful if the show is overcrowded or if one picture is a hopeless mess. If no picture name is present, the current picture is assumed. If you are not sure which picture is the current picture, type WHAT before you type PURGE. Note that when a picture name is present, you can purge a picture other than the current picture without affecting the current picture.

For further information on current picture and show, type HELP SHOW.

```
******************************************************************************

Sample Session:
(The symbols {} are used here to enclose what you type. Do not type them.)

GG > {STATUS}

Picture #1 Name: bigmap
          ...
Picture #2 Name: littlemap
          ...

GG > {PURGE bigmap}

GG > {STATUS}

Picture # 1 Name: littlemap
           ...

GG >

******************************************************************************
```

file HELP. PUR

GET Command

Format: GET <filename>
where <filename> represents the name of a data file in the DCTS1 computer.

Expanation: Specifies the data to be used to create a picture. The name of the data file must be known before running the GIGI show, and the file must be in one of three formats: random access numeric, standard raw data format, or GIGI format. (Type HELP FORMATS for more details on formats). If the data is not already in the final GIGI format, the GET command will prompt for further information so it can put it in GIGI format. (Type HELP LEGEND for details on this procedure.) The default data used in GIGI show is a 40 by 30 pixel area of downtown Hanover Landsat Band 7 data.

****

Sample Session:
The symbols {} are used here to enclose what you type. do not type them.

```
GG > {STATUS}

Picture #1 Name: ...
           GIGI file: GIGIHAN
           ...

GG > {GET GIGIMAP}

GG > {STATUS}

Picture #1 Name: ...
           GIGI file: GIGIMAP
           ...
GG >
```

The above is a sample where the data file named is in the final GIGI format; if it was not, there would be further prompts as outlined in HELP LEGEND.

****

file HELP.GET

COLOR Command

Format: COLOR <color scheme type>
where <color scheme type> is NEW, OLD, or DEF.

Explanation: Assigns colors to the GIGI display categories of the current picture. NEW indicates that you are creating a new color scheme for the data (It will prompt you for this), OLD indicates use of a color scheme saved previously in the permanent color library, and DEF sets the color scheme to the default: black, blue, red magenta, green, yellow, cyan, white (in that order). There are eight colors to choose from when creating a new color scheme -- they are listed in the last sentence.

****

Sample Session:
The symbols {} are used here to enclose what you type. Do not type them.

```
GG > {STATUS}

Picture # 1 Name: ...
            ...
            Colors: black blue red magenta green yellow cyan white

GG > {COLOR NEW}

Enter a color for each category. Valid colors are:
red, green, blue, magenta, cyan, yellow, black, white.
For forest ? {green}
For open ? {yellow}
For water? {blue}

GG > {STATUS}

Picture # 1 Name ...
            ...
            Colors: green yellow blue black black black black black

GG >
```

****

file HELP.COL

PUT Command

Format: PUT <port specification>
where <port specification> is either OWN or WHOLE, or a half screen (UPPER, LOWER, LEFT, or RIGHT) or a quarter screen (UPPER LEFT, etc.)

Explanation: Indicates where the current picture is to be displayed on the screen. (This location is called its "port".) Using OWN, you can specify the port exaclty using horizontal and vertical coordinates. (Assume that the origin of the coordinate system is at the lower left hand corner of the screen, and that the screen is one unit high and one unit wide.) WHOLE indicates that the port is to be the whole screen. UPPER, LOWER, LEFT, and RIGHT are used alone to specify half screens and in combination to specify quarter screens. The default port is the whole screen.

Warning: When there is more than one picture in the show, be careful not to specify ports which overlap -- only the most recently displayed picture will appear -- the ones before it in the overlap area will be obliterated.

Another warning: if you type PUT LOWER UPPER or PUT LEFT RIGHT, the whole GIGI show will blow up and you will have to start from scratch.

****

Sample Session:
(The symbols {} are used here to enclose what you type. Do not type them.)

```
GG > {STATUS}

Picture # 1: Name ...
             ...
             Port: 0  1  0  1

GG > {PUT LOWER LEFT}

GG > {STATUS}

Picture # 1: Name ...
             ...
             Port: 0  .5  0  .5

GG > {PUT OWN}

Enter values for port (left, right, bottom, top).
Assume that the screen is one unit high and one unit wide,
with the origin at the lower left corner
? {.2,.7,.3,.8}

GG > {STATUS}

Picture # 1: Name ...
             ...
             Port: .2  .7  .3  .8

GG >
```

****

file HELP.PUT

RENAME Command

Format: RENAME <revised picture name>
where <revised picture name> represents a character string which has not already been used as a picture name in the current show.

Explanation: Allows you to give a revised name to the current picture. Unlike the NEW command, it does not establish a new picture in the show; it just changes the name of the current picture. Useful if you find that the name of the current picture has already been used in the picture library, but you want to save it.

Type HELP SHOW for an explanation of "current picture" and "show"

****

Sample Session:

(The symbols {} are used here to indicate what you type. Do not type them.)

GG > {WHAT}

Current picture is "bigmap"

GG > {RENAME biggermap}

GG > {WHAT}

Current picture is "biggermap"

GG >

****

file HELP.REN

PAINT Command

Format: PAINT
        or PAINT ALL

Explanation: Once the specifications for a picture are set, you can use the PAINT command to display the picture. PAINT alone displays the current picture only. PAINT ALL displays the whole show. (Type HELP SHOW for an explanation of pictures and show.

Warning: there is no way to break out of the "painting" without making the whole show collapse. This is annoying if the painting is going slowly, but that is the way the cookie crumbles at this point. Type HELP GIGI for an explanatin of some of the hardware limitations of the GIGI terminal.

****

Sample Session:
(The symbols {} are used here to enclose what you type. Do not type them.)

GG > {PAINT}
(The screen will clear, and after a slight pause, the legend will print out on the left side of the port, the title of the data at the top, and then the picture will print out, pixel by pixel, left to right, top to bottom)

GG >

****

File HELP.PAI

STOP Command

Format: STOP

Explanation: STOP stops the GIGI Show and returns you to the DCTS monitor.

****

Sample Session:
(The symbols () are used here to indicate what you type. Do not type them.)

GG > (STOP)

****

file HELP.STO

ERASE Command

Format: ERASE

Explanation: ERASE merely clears the screen. It has no effect on the current picture or show. It is useful if one picture has been displayed and you want to eliminate it while you specify another.

****

Sample Session:
(Input from the terminal is enclosed in the symbols (). Do not type them.)

GG > (ERASE)
(screen clears)

GG >

****

file HELP.ERA

RESET Command

Format: RESET

Explanation: Clears out the current GIGI show and starts over, just as if you had started the program from scratch. Useful if your whole show is a hopeless mess and you want to start over without have to RUN the system again.

Sample Session:
(The symbols () are used here to indicate what you type. Do not type them.)

```
GG > (RESET)
(screen clears)

GIGI Show here ! Type HELP at any "GG >" for help.

GG >
```

file HELP.RES

APPENDIX D

DEVELOPMENT OF A REMOTE SENSING SYSTEM ON THE DARTMOUTH COLLEGE TIME SHARING SYSTEM

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Earth Sciences 32, Winter '82

DEVELOPMENT OF A REMOTE SENSING SYSTEM ON DARTMOUTH COLLEGE TIME SHARING SYSTEM

ABSTRACT

The intent of this project was to develop a system for the analysis of digital Landsat data. The design criteria required that the system should be user friendly, "bomb-proof", and very flexible.

At the present time the system contains operational histogram, greyscale, and linear stretch routines as well as a routine for printing the raw numerical data (reflectance values). Present plans call for the implementation of ratio, smoothing, and contrast enhancement routines in the near future. A classification routine should also be available reasonably soon.

The present data base is somewhat limited at the present time. All that is available is a 100 x 100 pixel grid centered on Hanover, N.H. Data for all four Landsat multispectral bands is available. The system can handle this data in up to 50 x 50 sections. The size of the section as well as its position in the data base can be determined completely by the user.

A number of improvements aside from adding more routines and improving the existing ones need to be made. The method for getting the data off tape and into a useable format is still somewhat rough and needs work to increase its reliability. The user interface also needs to be expanded to handle the user who is using the system for the first time. The system as a whole is very experimental and likely to remain so for some time yet.

DESIGN PARAMETERS

During the initial designing of DRESS (Dartmouth REmote Sensing System) a few parameters were used as general guidelines. The system had to be user friendly, "bomb-proof", and flexible. The first two parameters, of course, are intimately connected in the functioning of the system. At all points in the user interface where the user is requested to supply information provisions must be made to ensure that the information recieved will not cause the system to halt due to error. This accomplished by rather extensive use of SELECT/CASE structures which checks that the information fits within the allowable range. If the information is not valid, the user is told so, told why, and asked to try again. Undoubtedly there is information which would be accept by the system which would cause it to halt since it is impossible to cover all cases. The system does however approach the desired effect of not allowing the user to supply inappropriate information as well as telling them why it is inappropriate. The guidelines of being user friendly and "bomb-proof" dictated the amount and style of the user interface. The guideline of flexibility dictates the overall structure of the system.

The desire with flexibility was two fold. The user should be allowed to run any of the available routines on a data set,in any order, any number of times as well as be able to choose a new data set at any time without leaving the system. On a different level, the system as a whole should lend itself to modification and improvement with a minimal amount of disruption to the structure of the system.

The first parameter was met through the use of a group of nested

DO-LOOPs in the main program DRESS. This structure allows the user unlimited flexibility in the use of available routines and data. The only constraint is that one routine must finish running before another one is initiated.

The second parameter is handled by the overall structure of the system, that is one main program which calls a series of sub-routines to perform an operation. If one of the routines needs to be modified slighlty only the operations and corresponding information routines are affected. The main program and other subroutines remain untouched. Also if a new operation routine is added to the system only the subroutine which lists the available routines and the SELECT/CASE structure in the main program need to be altered. Therefore a routine which may or may not work can be incorporated into the system for debugging without hurting the overall effectiveness of the system.

THE COMPONENTS OF DRESS

Figure I is a flow chart depicting the logic of the main program DRESS. It is not truly representative of the present system in that the seperate libraries QUESTLIB, DATALIB, and SUBLIB have not yet been set up and all of the sub-routines are held collectively in one library on user number *22218E. If the system works sufficently well and proves useful and continues to expand it may be worthwhile to set the whole thing up in a seperate library on dcts devoted wholely to the system. Also the provision shown in the chart for saving output in a file in DATALIB has not yet been implemented. It is in QUESTLIB and SUBLIB that modifications to the system take place.

The programs and sub-routines which currently make up the system are:

DRESS - This is the main program which has the sole function of asking the user user what routine they would like to perform on the data set. It provides the framework for calling all of the information and operation routines as well as the structure for running a number of routines or using a number of data sets.

DATAQST - This routine asks the user to supply information defining the data set(s) they wish to access. At the present time it only allows information for one data set to be supplied.

DATAFIND - This routine retieves the data set(s) requested by the user in DATAQST and places it in a two dimensional array for use in subsequent routines. When provisions for ratioing and classification are implemented this, as well as DATAQST, will be expended to handle any number of data sets up to four depending on the needs of the user. Subsequent improvements will allow the created arrays to be saved in sperate files in DATALIB so DATAFIND will not need to be run continuously if an extended amount of work is to be done on a single data set or group of data sets. At the present time DATAFIND must be run everytime that the main program DRESS is initiated.

PROCLIST - This is simply a list and brief description of available routines.

DATALIST - This routine takes the raw numerical data in the array created by DATAFIND and prints it in matrix form at the terminal.

GREYQST - At the moment this routine simply asks if the user would like to perform a linear stretch on the data and if so what upper and lower bounds they wish to impose on the data. As the ratio, smoothing, and contrast enhancement routines become operational this routine will become more extensive.

GREYSCL - This is the heart of the operational part of the system right now. The GREYSCL routine prints a single overprint greyscale of the requested data and can be stretched according to the desires of the user.

It presently uses ten degrees of brightness in the greyscale print. In the future it will be possible to ratio, smooth, and contrast enhance the data.

HISTGRM - This routine prints a histogram of the data set breaking the data into groups with bandwidths of five reflectance units. (resulting in 26 "gates")

ANSWER - This is a small sub-routine used to check the reply to a question requesting a "yes" or "no" answer.

CAPCON - This is a sub-routine used to convert all letters to upper case to cut down on the amount of code needed in situations where the user can respond with more then three valid responses.

The following sample runs demonstrate the functioning of DRESS. DRESS was written in BASIC7 and can be run either by typing:

```
OLD DRESS
RUN
```

if the user is logged on to user number 22218E or by typing:

```
OLD *22218E:DRESS
RUN
```

if the user is on a different user number. The main program as well as the sub-routines were saved with a password (REMSEN) and any permanent changes must be replaced with that password.

MAIN PROGRAM - DRESS - FLOW DIAGRAM

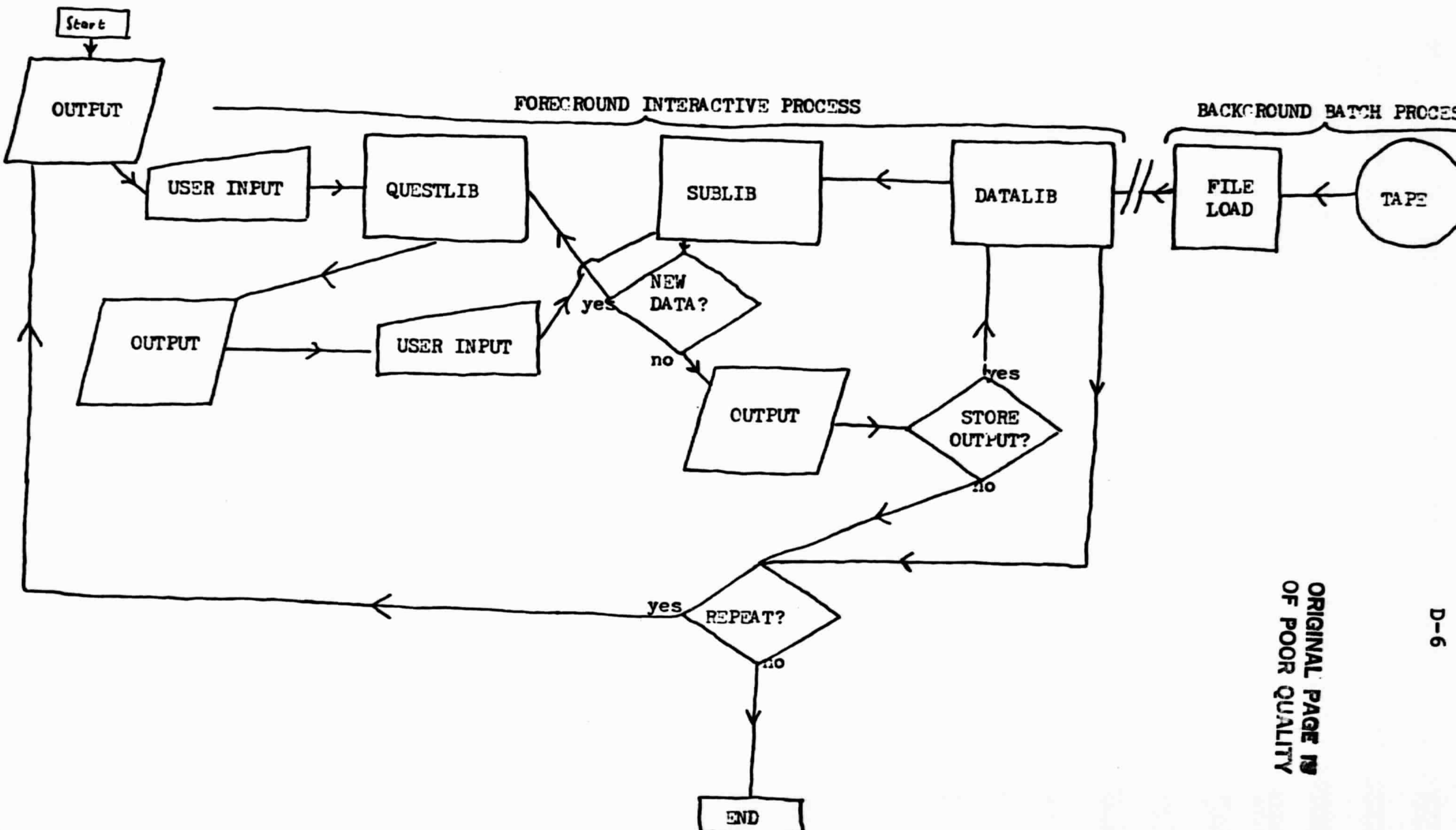

Fig. I

APPENDIX E

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